S
STATE LIBRARY OF PENNSYLVANIA
main,stks
Sketches in geology;
557.3J565
0 0001 00341883 5

SKETCHES IN GEOLOGY

CLASS 557.3 BOOK J 565

VOLUME

PENNSYLVANIA
STATE LIBRARY

Digitized by the Internet Archive
in 2019 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/sketchesingeolog00jill

BOOKS BY
Willard Rouse Jillson

Geology

Oil and Gas Resources of Kentucky, 1919-1920
Geology and Coals of Stinking Creek, 1919
Contributions to Kentucky Geology, 1920
Economic Papers on Kentucky Geology, 1921
Production of Eastern Kentucky Crude Oils, 1921
The Sixth Geological Survey, 1921
Oil Field Stratigraphy of Kentucky, 1922
Conservation of Natural Gas in Kentucky, 1922
Geological Research in Kentucky, 1923
The Coal Industry in Kentucky, 1922-1924
Kentucky State Parks, 1924-1927
New Oil Pools of Kentucky, 1926
Topography of Kentucky, 1927
Sketches in Geology, 1928
Geology and Mineral Resources of Kentucky, 1928
Geography of Kentucky, 1929

History

The Big Sandy Valley, 1923
The Kentucky Land Grants, 1925
Old Kentucky Entries and Deeds, 1926

Biography

Edwin P. Morrow—Kentuckian, 1922

Verse

Songs and Satires, 1920

Sketches in Geology

GLACIER CAPPED MOUNT SAINT HELENS FROM SPIRIT LAKE.

SKETCHES IN GEOLOGY

A group of twenty-two separate papers on American geology

By

WILLARD ROUSE JILLSON, Sc. D.

State Geologist of Kentucky, Curator Kentucky State Museum, and Lecturer in Geology at the University of Kentucky

ILLUSTRATED

C. T. DEARING PRINTING CO.
Louisville, Kentucky
1928

Copyright, 1928, by
WILLARD ROUSE JILLSON

All Rights Reserved

First Edition

PRINCETON
STATE LIBRARY

Dedicated to

WILLIAM MAURICE DEHN

With Abiding

Affection and Regard

243477

CONTENTS

Page

Contents ix
Illustrations xi
Greeting xiii

SKETCHES IN KENTUCKY

1. Geology in the Service of a New National Park..... 1
2. Asphaltic Coal 7
3. Depletion of Kentucky Crude Oils..... 11
4. Land of Ten Thousand Sinks..... 17
5. A Gigantic Slate Slide..... 19
6. The Haddix-Coalburg Geosyncline 21
7. Oil and Gas in the Big Sandy Valley..... 25
8. Occurrence of Cretaceous Sediments Between the Cumberland and Tennessee Rivers in Western Kentucky..... 31
9. Nest of Sinking Streams 35
10. Thoughts on Evolution 39
11. Valley-filled Areas of the Western Kentucky Coal-field..... 43

SKETCHES IN OTHER FIELDS

1. Volcanic Activity of Mt. St. Helens and Mt. Hood in Historical Time 49
2. New Evidence of a Recent Volcanic Eruption of Mt. St. Helens, Washington 57
3. Physiographic Effect of the Volcanism of Mt. St. Helens.... 63
4. Preliminary Note on the Occurrence of Vertebrate Footprints in the Pennsylvanian of Oklahoma 69
5. Emory River Overthrust of East Tennessee..... 73
6. The Harpeth River Dome 81
7. Early Mineral Explorations in the Mississippi Valley..... 89
8. A New Tennessee Oil Pool 117
9. Shading of Contoured Topographic Maps 125
10. Bibliography of the Geology and Paleontology of the John Day Region 133
11. Geology of the Amory Gas Field 143

Index 153

ILLUSTRATIONS

Glacier Capped Mount St. Helens from Spirit Lake.....Frontispiece

1. *Entrance to Mammoth Cave* 1
2. *One of the Caverns of the Mammoth Cave Region* 2
3. *Topography Mammoth Cave Region* 3
4. *Stalactites in Mammoth Cave* 4
5. *Topography Along Nolin River* 9
6. *Sink Hole Topography near Bowling Green* 17
7. *Cleared Railroad Right of Way at Burdine* 19
8. *Breast of Slide After Removal of Saturated "Slate"* 20
9. *Elkhorn Valley Below Burdine After the Slide* 21
10. *Profile of the Haddix-Coalburg Geosyncline* 22
11. *Outline of Oil and Gas Pools in the Big Sandy Valley* 26
12. *Cretaceous Sediments in Western Kentucky* 32
13. *Map of Sinking Stream Country* 36
14. *Alluviated Areas in Western Kentucky Coal Field* 44
15. *Desolate Upland Slopes of Mt. St. Helens* 49
16. *Mt. St. Helens—Gem of Cascade Topography* 51
17. *Rugged Topography Adjacent to Mt. St. Helens* 54
18. *Carbon Cast Lava From Mt. St. Helens* 57
19. *Virgin Forests of Fir Surrounding Mt. St. Helens* 58
20. *Mt. St. Helens a Typically Truncated Volcanic Cone* 65
21. *Topography of Mt. St. Helens and Vicinity* 67
22. *Casts of Footprints in Oklahoma Sandstone* 69
23. *Overturned Sandstone Slab With Cast Footprints* 70
24. *Emory River Flowing Along Fault Plane at Nemo* 73
25. *Geology of Brushy Mountain Region of Eastern Tennessee* 75
26. *Deformed Pottsville Sandstones in Fault Zone at Nemo* 77
27. *Crushed Sandstones Near Emory Fault at Deermont* 79
28. *Topography of the Harpeth River Valley* 81
29. *Areal Geology of Cheatham County* 83
30. *The Harpeth River Dome* 84
31. *Tilted Devonian Limestone on Flank of Dome* 86
32. *Marcom No. 1. Willow Grove, Tennessee* 117
33. *Chattanooga Shale on Limestone of Richmond Age* 118
34. *Geology of the Celina District* 119
35. *Kerr No. 1. Discovery Well, Kettle Creek, Kentucky* 121
36. *Northeast Flank. Willow Grove Anticline* 123
37. *Portion of Monument Springs Sheet* 126
38. *Portion of Williamsport Sheet* 128
39. *Portion of Cave-in-Rock Sheet (Kentucky)* 130
40. *Cretaceous Upland Near Amory* 143
41. *Mississippi's First Gas Well* 145
42. *Amory Gas Field and Adjacent Oil and Gas Pools* 147
43. *Typical Mississippi Rig* 149

Greeting

Kentucky—

A GLORIOUS Commonwealth, neither too far north nor too far south, too far east nor too far w e s t not a little too hot nor a bit too cold, never arrogantly rich nor beggardly poor; a wonderful State where bluegrass and rhododendron are native, cordiality and humor an inheritance; virtue and independence a religion—in panorama an exquisite blending of rugged sandstone mountains, broad limestone plateaux, and rich alluvial valleys; bedded with vast deposits of coal, petroleum, natural gas, asphalt, clays, building stones, calcite, barite, fluorspar, and metaliferous ores; broadly overrun by a net of navigable streams great as a potential source of hydro-electric power—Kentucky, a land of good living and unexcelled opportunity both in town and country—Kentucky, a traditional synonym for hospitality, romance and ancestral Americanism—Kentucky, I say, from the Cumberlands to the Mississippi, sends you an old Yuletide greeting, with best wishes for a MERRY, MERRY CHRISTMAS and much of good cheer throughout the coming year.

W. R. Jillson

Old Capitol
Frankfort, Ky.
December 20, 1928

Director and State Geologist
The Kentucky Geological Survey

PART ONE

Sketches in Kentucky

I

GEOLOGY IN THE SERVICE OF A NEW NATIONAL PARK*

Nature and man combined in the seventeenth and eighteenth centuries to locate most of the National Parks in the western United States. Man and nature working together in the nineteenth and twentieth centuries have begun to establish a number of National Parks east of the Mississippi River. Curious as these statements may appear to be at first glance, they are founded upon well established geological and historical facts. The causal sequence of earth and human events which gave order to such an

ENTRANCE TO MAMMOTH CAVE

extraordinary group of recreational areas is quite as interesting in review as it is unusual.

No one, of course, will deny that Nature sponsored all of our western National Parks during the latest of the mountain-making geological periods—the "Tertiary." It was then that the great chain of the Rockies and the Cascades were finally uplifted and sharply defined. Were these mountains not so youthful the grand scenery which so widely characterizes them would long ago have been lost through the beveling action of erosion. European colonization in America, as everyone knows, found its greatest expansion two or three hundred years ago along the

*Kentucky Progress Magazine, Vol. 1, No. 2, pp. 15-16 and 36, October, 1928; also Pan-American Geologist, Vol. L, No. 4, pp. 268-270, November, 1928.

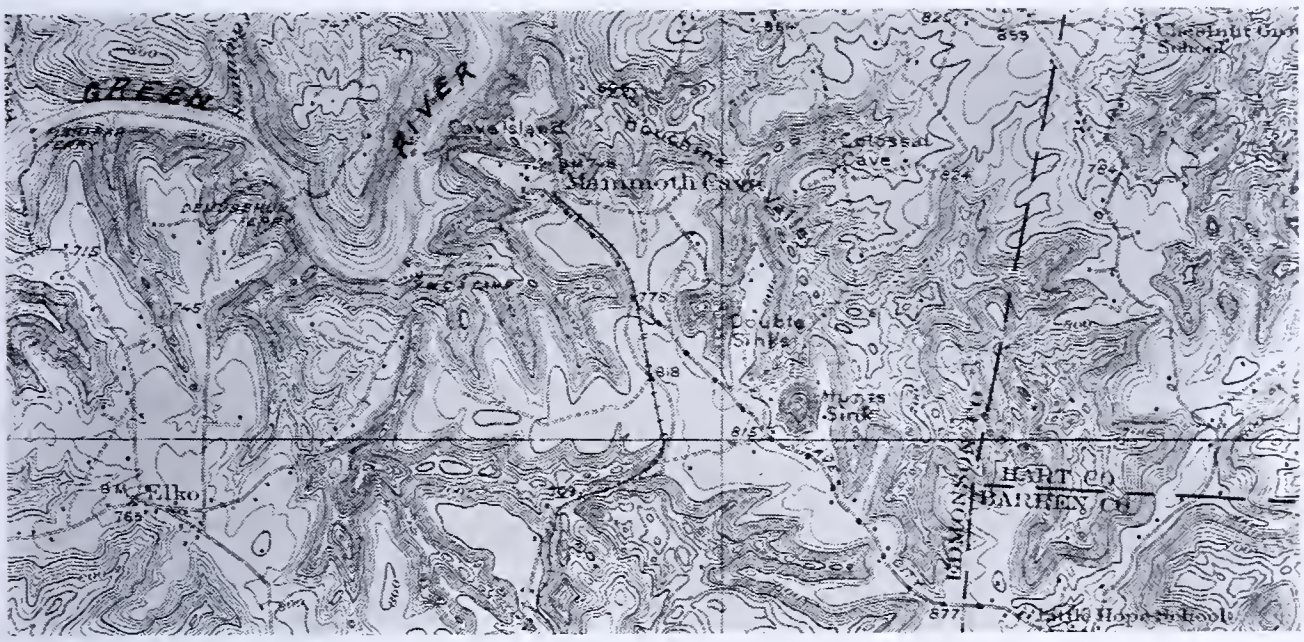
Atlantic seaboard. The scenic upland West, to a large degree unsettled and unclaimed, thus became the inheritance of the nation. By easy and inexpensive transition suitable areas became National Parks—the Hot Springs, Yellowstone, Yosemite, Mt. Rainier, Glacier, Grand Canyon, and the rest.

ONE OF THE MANY GREAT CAVERNS OF THE MAMMOTH CAVE REGION

Scenic beauty, however, is not alone typified by craggy peak and yawning chasm. As in aged human features, there is a beauty in the softened mellow contour of old mountains quite as delightful and inspiring as that found in the rugged youthful ranges and abysmal gorges of a geologic yesterday. Apparently

so minded. nature lovers in America have turned. in some part at least, from the grandeur of the high and arid West to the wave-washed rounded and timbered mountains of the East. Man assisted by nature established the first of these eastern parks, the Lafayette National on Mount Desert Island off the Maine coast, scarcely a decade ago.

During the last few years this growing movement for the setting aside of additional national parks in the Eastern United States has culminated in the Congressional enactment authorizing the Shenandoah National Park, in Virginia; the Great Smoky National Park of Tennessee and North Carolina; and Kentucky's



TOPOGRAPHY MAMMOTH CAVE REGION

world-wide scenic wonder—the Mammoth Cave National Park in the Green River Valley. Others will some time follow.

Best known and most accessible of all the great caverns of the world, the Mammoth Cave National Park—soon to be—has had a most interesting history. This cave, known by the Indians, was discovered by white men about the time of Statehood—upwards of 150 years ago.

Intermittent explorations during the past century have resulted in opening in this district many adjacent limestone caves and caverns, all of which possess an everchanging geological panorama of subterranean beauty. Most important among these are Colossal Cave, Great Onyx Cave, Crystal Cave, and Salt Cave, but there are many others. Since no broad public domain—in the western sense—exists in Kentucky, by the very nature of

their discovery, these caverns including the Mammoth Cave became individual property. As such they have remained down to this early part of the twentieth century.

Sensing in 1920 the rising tide of public interest in the unduplicatable wonders of the Mammoth Cave region, the Kentucky Geological Survey, acting upon its own volition, sponsored a gradual educational program of earth sciences for this district. Accordingly, modern detailed topographic maps were made for those portions of the Mammoth Cave region involving Edmonson, Warren, Barren and Hart Counties. An appropriate scale was selected for these quadrangles, twenty feet in contoured interval and nearly one inch to the mile, thus allowing any intelligent

STALACTITES IN MAMMOTH CAVE

visitor in the Mammoth Cave area an accurate understanding of the curiously sculptured surface of the earth in this immediate vicinity. Closely following upon the completion of this work, a detailed geological survey with map was made of the cavern county—Edmonson. In this a discussion of the origin of the Mammoth Cave and associated caves was clearly set out by text and diagram. About the same time an illustrative booklet on State Parks in Kentucky was issued in which the chief areas of scenic interest were described. Prominently featured in a separate discussion in this book which has now gone into its second edition may be found interesting geological and physical descriptions of the Mammoth Cave region.

The centering of geological attention upon a district naturally

so unique and wonderful as the Mammoth Cave region resulted logically in a broad re-awakening of the importance of this district and its suitability as a national park. The dormant germ of national park enthusiasm centering about the Mammoth Cave area leaped into flame. A strong and virile association grew into being. Maps, documents, and booklets prepared by the Kentucky Geological Survey became the basis of an authoritative demand for the creation of a national park at Mammoth Cave. Unlimited time and treasure were ushered into the great adventure by its sponsors in Bowling Green, Louisville, and Frankfort. Indefatigable and well directed effort finally succeeded in insuring Congressional approval of the establishment of the new National Park in Kentucky.

Continuing nevertheless in its support of the national park movement, the Kentucky Geological Survey initiated last spring a detailed examination of the district and has now prepared and published one of the most attractive geological guide books of its kind that has ever been issued for a national park. Nearly one-third of the entire edition has now been exhausted within the first month following its issuance. At the present time the Kentucky Geological Survey is taking active steps towards the preparation of a detailed to scale subterranean model of the Mammoth Cave region. This unique model in duplicate when completed will be exhibited permanently within the new National Park area and in the collections of the Kentucky Geological Survey at Frankfort. A detailed surface and subterranean biological survey is planned for this cavernous district during 1929 the results of which it is hoped will somewhat advance our knowledge of the fauna living and extinct in this most interesting part of Kentucky.

II

ASPHALTIC COAL*

Unique in a list of about twenty-five high grade Kentucky coals, including steam, domestic, gas, and coking-bituminous, and cannel grades, all of which are of growing industrial importance, there occurs an asphaltic coal—the Nolin seam (Pottsville) of Edmonson and Grayson Counties. The Nolin coal has been correlated with Dr. David Dale Owen's 1-B[1]. While this coal as a commercially important body covers a unit area of about 250 square miles (drainage cut-outs not excepted), only a relatively small area, possibly not more than 20 square miles, is impregnated with asphalt. The asphalt is found not in the coal itself but as a filler within the crevices of the coal, which, it should be pointed out, is completely fractured in the bed. These fractures, no doubt, have had their origin in the structural strains and stresses to which this regional sedimentary block has been at various times subjected.

The asphalt-enriched portion of the Nolin coal centers about Kyrock postoffice on the Nolin River in Northern Central Edmonson County, and has been noted in the literature.[2] It has never, however, been adequately described, nor has an hypothesis been advanced for its occurrence. The following notes are based upon original field investigations of the writer, which includes sampling of the coal, during October, 1919, and January, 1920.

The Nolin coal (Pottsville) occurs about 350 feet above the top of the Mississippian series in the type asphaltic locality which is found on the headwaters of Pigeon, Dismal, Second, Bylew, and some adjacent creeks, all tributaries of the Nolin River, which in turn is a south-flowing tributary of the Green River.

On the head of Pigeon Creek near the road leading from Kyrock to Sweden postoffice this asphaltic coal occurs at an elevation of about 780 feet. Dipping to the north from this point, and occupying a well defined syncline it outcrops at lower elevations on Dismal Creek beneath a strong bed of bituminous sandstone—

---

*Transactions Kentucky Academy of Science, Vol. I, pp. 78-81, 1924.

[1]Miller, A. M., Geology of Kentucky. Ky. Geol. Survey, Series V, Vol. II, p. 283.

[2]Bryant, J. Owen: The Economic Geology of a Portion of Edmonson and Grayson counties, Ky., Ky. Geol. Survey, Series IV, Vol. II, Part I, pp. 177-178, 1914.

"rock asphalt." On Dismal Creek the Nolin coal has been opened at a number of points for domestic use. Here this coal has a thickness of about 36 inches with a blue shale roof and fire clay bottom. Although the Nolin coal shows high in ash, ranging generally from 6 to 12%, and fairly high in sulphur—2 to 3%, its asphaltic content, varying from 4 to 5% is also considerable. This latter quality renders it easily ignitable, and therefore keeps it much in demand throughout the countryside. Removed about 15 miles from the nearest railroad, and therefore not accessible from an industrial standpoint, this asphaltic coal enjoys a good local reputation and finds a considerable use for domestic heating and cooking, and smithing.

Within general limitations the particular region in which the Nolin coal is enriched with asphalt, coincides with one of the several regions of unusual enrichment of "rock asphalt"—the bituminous sandstone of this portion of Edmonson and Grayson Counties. On Pigeon Creek the rock asphalt occurs in the Pottsville conglomerate at a point about 230 feet above the top of the Mississippian series. The asphalt impregnation at this point averages about 25 or 30 feet in thickness, and 6 to 7% in bituminous matter. A second, but thinner and leaner bituminous sandstone occurs irregularly at some little distance above this main strata of rock asphalt. In between these bituminous strata occur sandstones and shales barren of any bituminous matter on the outcrop. Superimposed upon this second or upper ledge of rock asphalt, occurs another sequence of barren sands and shales, and at an altitude of 780 feet, or 120 feet above the main body of rock asphalt, occurs the asphalt-impregnated Nolin coal.

The distinctly disconnected bed positions of these three asphalt-impregnated bodies, their synclinal position and regional coincidence suggest the development of vertical or semi-vertical joint plane or fissure connections from the lowest and richest bituminous sand body up through the second and leaner sand body into the Nolin coal long after the completion of the coal forming process. The marked degree of asphaltic impregnation of the crevices of the Nolin coal in this region is interpreted as indicating that the liquid bitumens were forced into the coal

TOPOGRAPHY ALONG NOLIN RIVER
This view in Edmonson County was taken from an army airplane.

under hydraulic pressures at a comparatively recent date geologically and chronologically, though from an historical standpoint in the remote past.

Such a thorough impregnation, even with as light a petroleum as are most of these of Pennsylvanian age in Kentucky, could only have occurred during a time of considerable regional depression, possibly in the late Mesozoic or early Cenozoic times. It is assumed that the liquid bitumens were gradually moved upward through the geological section by gravity pressures of the saline waters of deposition until the considerable regional uplift which followed the period of depression arrested the movements, and locked the crude oil in place in the Nolin coal.

Subsequently the Nolin River entrenched itself in the broad plateau framed by the uplifted Coal Measures of this part of Edmonson County, and exposed beneath the Bee Springs sandstone basal Pennsylvanian. This process brought to outcrop, (1) the Nolin coal, (2) the thin upper rock asphalt beds, (3) the main lower body of rock asphalt (conglomeratic), and (4) the upper limestones and shales of the Mississippian series. In the course of the entrenchment of this drainage system practically all of the volatile constituents of the petroleum in the Nolin coal and the underlying conglomeratic sandstones made their escape by way of the outcrop, leaving only a tarry or asphaltic residue. The most recent event in the geologic history of the region is a well substantiated subsidence of the entire lower Green River basin, which has resulted in pondering of these waters, valley filling of all lowlands, and a certain reduction in elevation of all regional stratigraphic units, including the Nolin asphaltic coal.

Presented before
Kentucky Academy of Science
May 8, 1920, Lexington, Ky.

III

DEPLETION OF KENTUCKY CRUDE OIL*

Since the year 1900, when, with a production of 62,259 barrels, the petroleum-producing industry may rightly be said to have gained its feet in Kentucky, there have been many who have held it impossible for the State to become an oil producer of national importance. Others on the contrary, and to them we owe unmeasured gratitude, have steadfastly claimed a bright future for the oil operator in Kentucky. An analysis of the crude oil production figures for Kentucky for the twenty-two years which have elapsed since 1900 will do much toward presenting the truth of the matter, and aid in arriving at depletion estimates of future petroleum production for the Commonwealth.

Although oil was first produced in Kentucky on the South Fork of the Cumberland River in 1819, nothing came of the discovery for many years. The increasing number of "wildcat" wells which were drilled in various parts of the State served to index oil-producing areas rather than to augment the annual total of barrels produced. The earliest oil production figures of which we have an accurate account are for 1883, and show only 4,755 barrels for the whole State of Kentucky. From this time on until 1899 the total annual production of the State ranged up and down from 3,000 to 9,000 barrels. At the end of the eighth decade following the first oil strike in Kentucky, it would have been impossible for anyone to have predicted with accuracy what the future score of years, now passed, might have brought forth. In the same way it is hazardous at the present to predict the rise and fall of crude oil production in Kentucky, though with a certain fairly large production now established, and with the State pretty generally "wild-catted" by geologists and operators alike, there is considerably more to work upon now than there was twenty years ago.

Certain established factors based on the economic and industrial life of this country, such as the increasing demand for gas engine gasoline, industrial lubricants, and fuel oil, coupled with the central eastern location of this State, will tend as the years go by to keep Kentucky well up in the ranks of the oil-

*Transactions Kentucky Academy of Science, Vol. I, pp. 122-127, 1924.

producing states. These factors have operated in New York and Pennsylvania for many years to put off the day of final and complete depletion. The same principles are now operating in Kentucky, and will continue to operate even more vigorously in the future.

A review of the production figures for Kentucky, when plotted in the form of a curve, shows a well defined cycle of acceleration, followed by declining production extending from the year 1900 through to the year 1910. This period witnessed the development of Ragland, Wayne County, Campton, Irvine, Bussyville, and Fallsburg pools. From a minimum production of 2,259 barrels in 1900 oil production rose to a peak of 1,217,337 barrels in 1905, which was essentially maintained through the year 1906, when, 1,213,548 barrels were produced.

Crude oil production then dropped until 1910 when only 468,774 barrels of petroleum were produced in the State of Kentucky. This figure continued to be about the index of production through to the year 1915, when the impetus brought about by the wartime prices of gasoline, lubricants, and fuel oils, expressed itself in a greatly renewed interest in "wild-catting," and resulted in a substantial increase immediately. Petroleum production jumped in 1916 to 1,144,750 barrels, and in 1917 and 1918 successfully passed the three and four million barrel mark. The peak of the recent extensive oil production in Kentucky was attained in 1919 when a total of 9,226,473 barrels, and a position of eighth among the oil-producing states was secured. This advance, great for any Appalachian State, carried with it a vast amount of speculation by Kentuckians and others, which was largely responsible for the development.

A slowing up of industry following the close of the war, shortly induced very much lowered prices for Kentucky crude oil and cast a doubt in the hearts of producers. In 1920 the total production of the State dropped to 8,546,027 barrels. The interest in oil development, however, had been sufficient during the five years preceding to bring about the discovery of several large producing pools widely distributed throughout the State of Kentucky. Chief among these in the order of the productivity were the Big Sinking, Ashley, Ross Creek and Station Camp; and other smaller pools in Estill, Lee, Powell, and Wolfe

Counties; the grouped pools of Allen, Barren, and Warren Counties; the associated pools of Johnson, Magoffin and Lawrence Counties; and the widely extended pools of Wayne, McCreary, Clinton and Cumberland Counties. A strengthening of the price of crude oil resulted in the extension and stabilization of the oil-producing industry in Kentucky during 1920. At the end of the year petroleum production amounted to 9,080,845 barrels, an increase of 534,818 barrels during the year.

To the casual observer this increase has little significance, but when one considers that the principal producing pool of the State, the "Big Sinking," in Lee County, decreased steadily at a rate averaging nearly 10,000 barrels a month, it will be seen that this increase really meant the discovery and large development of other new pools elsewhere in the State. These pools were those of the Johnson, Magoffin, and Lawrence County region, and those of the Allen and Warren County region. A statement of the amount of petroleum produced in Kentucky from 1883 to the present time follows:

PRODUCTION OF PETROLEUM IN BARRELS IN KENTUCKY FROM 1883 TO 1927*

1883	4,755
1884	4,148
1885	5,164
1886	4,726
1887	4,791
1888	5,096
1889	5,096
1890	6,000
1891	9,000
1892	6,500
1893	3,000
1894	1,500
1895	1,500
1896	1,680
1897	322
1898	5,568
1899	18,280
1900	62,259
1901	137,259
1902	185,331
1903	554,286

*Figures for the years 1922-1927 have been added.

1904	998,284
1905	1,217,337
1906	1,213,548
1907	820,844
1908	727,767
1909	639,016
1910	468,744
1911	472,458
1912	484,368
1913	522,550
1914	479,609
1915	407,081
1916	1,144,750
1917	3,015,640
1918	4,035,950
1919	9,226,473
1920	8,546,027
1921	9,080,845
1922	8,889,303
1923	8,087,250
1924	7,437,232
1925	6,658,803
1926	6,264,502
1927	6,628,110
	88,620,345

In predicting the figures of crude oil production likely to be obtained in Kentucky in the future, estimates of certain and sure depletion now in evidence in many of the oil pools of this State, must be coupled with an unknown fraction representing oil produced from new pools now undiscovered. This latter factor is very much more difficult to ascertain than is an estimate of depletion which may be figured with some reasonable degree of precision.

The price of crude oil is also an important factor in the ultimate amount of petroleum which will be produced in Kentucky. With a return at any time to extended low schedules for crude oil will come great demoralization in the producing industry in Kentucky, especially in the small and old well districts. On the other hand an increased price and a sustained demand for crude oil in the near future will tend not only to strengthen the entire industry as it now stands developed, but

PENNSYLVANIA
STATE LIBRARY

also to induce widespread "wild-catting." If the price of crude oil strengthens slightly and remains more or less stationary during the next several years, it seems reasonable to anticipate a production in Kentucky which will range between seven and nine million barrels, probably close to eight million barrels.

The tenacity of some of the older wells in Kentucky, especially in the "true sand" districts of eastern Kentucky, is surely indicative of a somewhat more sustained production for these districts especially; and in the end for the entire State, than had at first been assumed. Estimates of depletion for Kentucky made but a year ago, giving undue importance to the rapid decline of the "Big Sinking" and associated pools, and assuming that Warren County had reached its peak, must now, it appears, be revised in consideration of the new elements of long life introduced by the proving up of the characteristic of Eastern Kentucky pools.

It is figured that the oil pools of Kentucky as now known and partly developed will still afford production through wells which are yet to be drilled, until the year 1980. For this period, 1922 to 1980, inclusive, it is figured that the known pools of Kentucky will produce 120,000,000 barrels of crude oil. Pools yet to be discovered in this State it is estimated will produce 80,000,000 barrels; a total of 200,000,000 barrels of petroleum now in the ground. A total volume of 44,655,145 barrels for the period 1883 to 1921, inclusive, has been produced. The total production of petroleum from discovery in Kentucky from 1819, to date may be listed as follows:

Petroleum produced in Kentucky:

1819 to 1882 inclusive (unmeasured, estimated)	144,000 bbls.
1883 to 1921 inclusive (actual oil runs)	44,655,145 bbls.
1921 to 1980 inclusive (figured decline known)	120,000,000 bbls.
1922 to 1980 inclusive (estimated undiscovered new production)	80,000,000 bbls.
Total petroleum reserves	244,799,145 bbls.

Of the above total of approximately 205,000,000 barrels, 44,799,145 barrels have been produced and consumed. The figured depletion of 120,000,000 barrels is regarded as conservative. It amounts to about 1,500,000 barrels annually until

243477

1980. The estimate of 80,000,000 barrels of unknown, undiscovered oil in Kentucky is probably well within reason and probability for the period for 1922 to 1980, though it affords, it must be admitted, the greatest element of probable error in these calculations. With something over 200,000,000 barrels of petroleum reasonably possible for this State, Kentucky's place among the oil-producing states of the Union, and especially those of the Appalachian district, seems assured.

Presented before
Kentucky Academy of Science
May 20, 1922, Lexington, Ky.

IV

LAND OF TEN THOUSAND SINKS*

The pitted or sink hole characteristic of the St. Louis and Chester divisions of the Mississippian System in Kentucky has long been recognized. The widely ramifying sub-surface drainage developed in these limestone rocks, which are frequently of high purity, is well exemplified in the Karst and cave region of Edmonson County, Kentucky, and in the natural sewage channels of the city of Bowling Green, Warren County, Kentucky. The peculiar topographic figure of the "sink" country is well shown on either side of the Louisville and Nashville Railroad,

SINK HOLE TOPOGRAPHY NEAR BOWLING GREEN

and the Dixie Highway from Munfordville in Hart County to Bowling Green, Kentucky.

The recently completed Mammoth Cave topographic sheet exhibits 2,833 sink holes, and is regarded as a model for students. The number of sinks on other completed quadrangles follow: Brownsville, 1,150; Bowling Green, 2,563; Princeton, 1,429; and Monticello, 1,096, giving a total of 9,071. The Brownsville topographic sheet shows the largest mapped sink hole just south of Dripping Springs escarpment, and located between Girkin and Tuckertown postoffice. This gigantic sink has an area of 4,865 square miles or 3,114 acres. It is estimated on a basis of mapped areas that the Mississippian plateau

*Transactions Kentucky Academy of Science, Vol. I, pp. 143-144, 1924.

in Kentucky contains between sixty and seventy thousand sink holes of varying size and description.

Abstract of paper presented before
Kentucky Academy of Science
May 12, 1923, Lexington, Ky.

V

A GIGANTIC SLATE SLIDE*

The largest and most destructive "slate slide" in the history of mining operations in Kentucky occurred at Burdine, Letcher County, on the waters of Elkhorn Creek adjoining the northwest flank of Pine Mountain, on February 3, 1923. About 125,000 cubic yards of "slate" taken from the parting of the Elkhorn coal (Pottsville) at Mine No. 201 of the Consolidation Coal Co., and

CLEARED RAILROAD RIGHT-OF-WAY AT BURDINE

gobbed in Slate Hollow became super-saturated with rainwater and wash during an abnormal precipitation of 3.27 inches for the 48 hours immediately preceding the slide.

The direct causes of this slide were: (1) abnormal precipitation combined with inadequate sub-slate drainage, (2) unstaple angles of rest (35 degrees) on the breast of the fill, (3) excavation and ditching operations following the first minor slips, (4) seismological disturbances of record, and (5) unusual regional geotectonic relationships. The total length of the slide was 929 feet. The semi-liquid "slate" moved out fan-shaped entirely across the bottom of Elkhorn Creek to a maximum depth of 75 feet. The movement was entirely within the

*Transactions Kentucky Academy of Science, Vol. I, p. 146, 1924.

BREAST OF SLIDE AFTER REMOVAL OF SATURATED "SLATE"

"gobbed slate" and did not affect the underlying country rock or soil. Casualties were narrowly avoided.

Abstract of paper presented before
Kentucky Academy of Science
May 12, 1923, Lexington, Ky.

VI

THE HADDIX-COALBURG GEOSYNCLINE*

During recent years much interest has been evinced by geologists, engineers and others in the exact location and nature of the geosyncline of Eastern Kentucky. It was shown by the writer in 1919, that this geosyncline, so evident in the surface rocks (Pennsylvanian), was in fact a feature of economic importance only in the Coal Measures, since their great and rapid thickening to the southeast obliterated it in all Mississippian and older strata. Structural work now approaching completion in the trough portion of the Eastern Kentucky coal fields—all

ELKHORN VALLEY BELOW BURDINE AFTER THE SLIDE
For detailed description see pages 19 and 20.

elevations being reduced to the Fire Clay Coal as the key horizon—shows definitely that the line of low points in the Coal-measures, known in the Kentucky literature as the Haddix or Eastern Kentucky Geosyncline, enters the State from Tennessee at an elevation of 1,600 feet in the vicinity of Jellico, Whitley County, and progresses irregularly northeastward through Knox, Clay, Perry, Breathitt, Magoffin, Floyd and Martin Counties. In the southwestern part of Martin County this major syncline narrowly escapes a plunge to the north through Martin County to join the deep geosyncline which, progressing southwestward

*Transactions Kentucky Academy of Science, Vol. I, pp. 144-145, 1924.

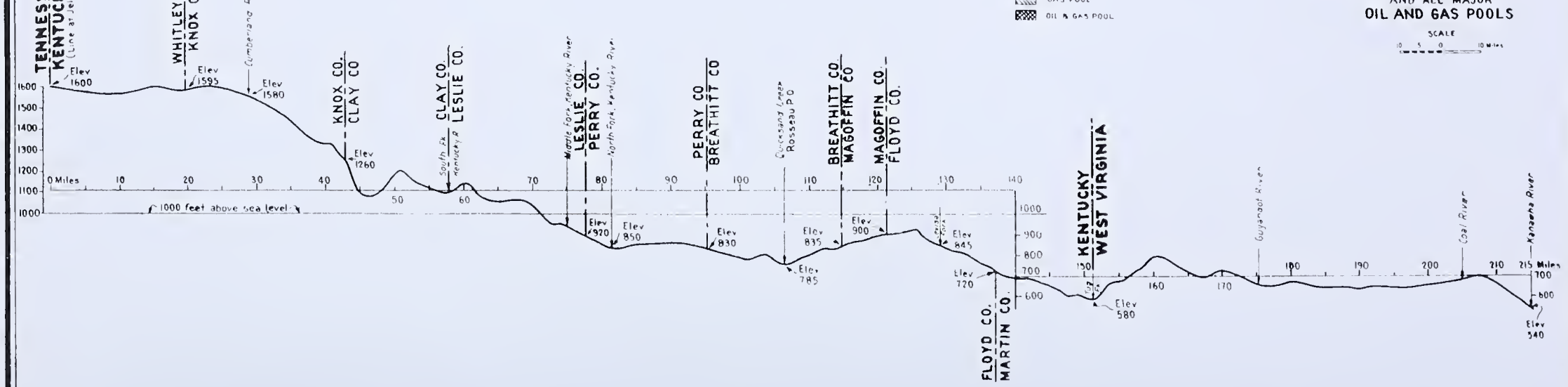
PROFILE OF GEOLOGICAL STRUCTURE
OF THE
HADDIX-COALBURG GEOSYNCLINE
OF
EASTERN KENTUCKY AND SOUTHERN WEST VIRGINIA

BY W. R. JILLSON
STATE GEOLOGIST OF KENTUCKY
1928

Key bed Fire Clay (No 4) Coal—Pottsville (Kentucky)

LEGEND
- OIL POOL
- GAS POOL
- OIL & GAS POOL

KEY MAP SHOWING
GEOGRAPHIC RELATIONSHIP
OF THE
GEOSYNCLINE
AND ALL MAJOR
OIL AND GAS POOLS
SCALE
10 5 0 10 Miles



PROFILE OF THE HADDIX—COALBURG GEOSYNCLINE

through West Virginia, terminates abruptly in Lawrence County, Kentucky.

The Eastern Kentucky geosyncline (Haddix) leaves Kentucky just south of Wolfe Creek on the Tug Fork of the Big Sandy River at an elevation of 580 feet, and continues on to the northeastward as the Coalburg Syncline of West Virginia, passing through Mingo, Logan and Boone Counties into Kanawha County where it dies out in a broad monocline on the headwaters of Blue Creek of Elk River at a point about 12 miles east of Charleston. Where it crosses the Kanawha River at Coalburg it has a computed elevation of about 540 feet indicating a drop of 1,060 feet in the Fire Clay Coal in course. Of this great northeastward fall, 1,020 feet were completed in Kentucky.

A study of the profile of the Haddix-Coalburg Geosyncline (plotted by the writer to scale) brings out clearly for the first time the following facts:

I. This geosyncline is divisible into three units: (1) Kanawha River westward to Tug Fork. Low elevations between 580 and 540 feet. (2) Tug Fork southwestward to Middle Fork of Kentucky River in Perry County. Low elevations between 855 and 580 feet. (3) Middle Fork of Kentucky River to Jellico region (Tennessee line). Lowest elevation 855 feet and highest elevation 1,600 feet.

II. Regional coincidence of pronounced structural highs in Floyd and Clay Counties with important developed gas fields, and lack of coincidence with large and important developed oil pools in all of its course until the Cabin Creek region of southern Kanawha County, West Virginia, is entered.

III. Coincidence of synclinal structure with all lines of major drainage from the South Fork of the Kentucky River northeastward to the Kanawha River.

Revision of paper presented before
Kentucky Academy of Science
May 12, 1923, Lexington, Ky.

VII

OIL AND GAS IN THE BIG SANDY VALLEY*

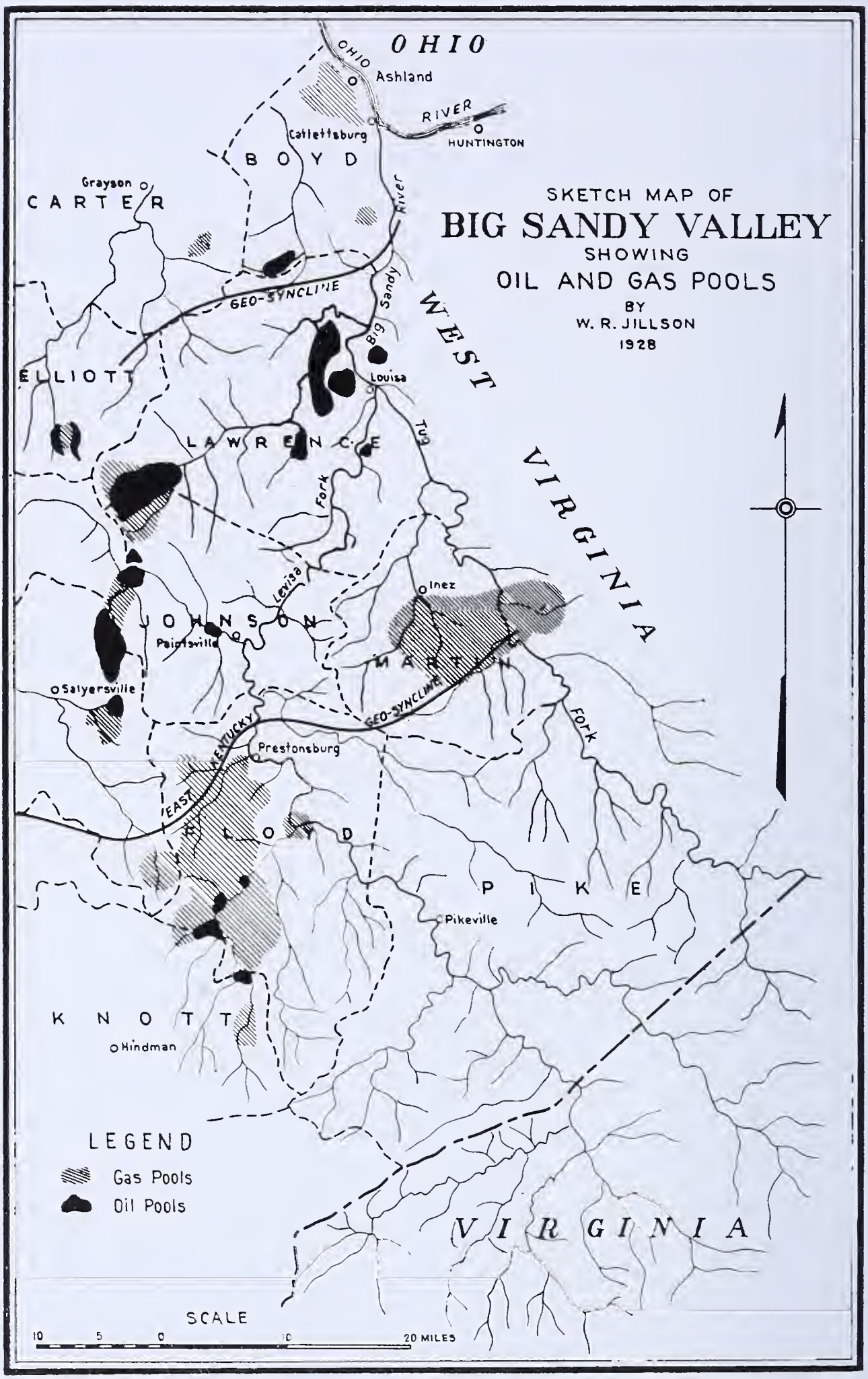
Explorers and hunting parties in the Big Sandy Valley of Kentucky prior to Statehood found natural gas seepages in the creek and river bottoms at many points. To these they applied fire, with the result that they became burning springs, and widely known. "Rock oil" seepages too were discovered in this region by the first settlers, and as early as the 50's a number of attempts had been made to recover this new earth product in larger than natural quantities. But the mechanics of well drilling, then limited to a spring pole, was not thoroughly understood, and the science of geology, now of recognized importance in oil and gas prospecting, was quite unappreciated.

With the coming of the Civil War the efforts which had been made in Boyd, Lawrence, Johnson, and other counties in the Big Sandy Valley to secure petroleum were abandoned. Not until a much later date indeed did experienced oil men coming down from the proven fields of the northeastern States of New York, Pennsylvania, and Ohio look with anxious eyes for the prospect of new oil pools in eastern Kentucky. One of these early pioneers, Louis H. Gormley, of Newcastle, Pa., pole boating all of his rig irons, cables and tools up the Big Sandy in 1890, drilled in the first well in the Beaver Creek valley at the mouth of Salt Lick in Floyd County in 1891. He secured oil from the Pottsville sands in paying quantities in what is now recognized structurally as a local basin syncline. An interesting outgrowth of his "wild catting" efforts was the organization of the New Domain Oil and Gas Company holding the Beaver Creek oil production. A few years later this corporation became a Standard Oil subsidiary, with headquarters in Pittsburgh and divisional branches in several parts of the United States.

A drilling boom throughout the Big Sandy Valley then followed the Beaver Creek oil strike, but unfortunately little attention was paid to the geology of the region. Gas had been discovered in Martin County in 1881 and allowed to waste for ten years, when it was closed in and used to manufacture carbon

---

*The Register of the Kentucky State Historical Society, Vol. 20, No. 59, pp. 191-193, May, 1922.



OUTLINE OF OIL AND GAS POOLS IN THE BIG SANDY VALLEY

black. Floyd County gas was discovered at several points, and some "wild cat" wells showing both oil and gas were drilled in Johnson and Lawrence Counties. Pike County was drilled unsuccessfully, as were a number of other eastern Kentucky counties.

Beaver Creek finally developed an oil pool of small size, and a gas pool of undetermined size, production coming from the Pottsville (Pennsylvanian) and Maxton (Mississippian) sands. Martin County gradually developed a gas pool of large size on the Warfield anticline, production being secured from the Maxton, Big Lime, Big Injun and Berea (Mississippian) sands. In 1901 a public utility gas line came into the field and development became rapid. The Martin County gas field reached its peak of production in 1914-1915, nearly a quarter of a century after the original opening of the Beaver Creek oil and gas pool.

By 1915-1916 practically all of the old time "wild catters" had left the Big Sandy Valley. As the field became more open a few companies employing geologists took an interest in the region and endeavored to do what the "wild catters" had failed in doing—open a new large oil pool. The persistent efforts of a number of geologists separately and in collaboration resulted finally in determining the figure more or less exactly of a great uplift of regional dimensions which had for its axis a nearly north and south line, passing along the boundary between Johnson and Magoffin Counties, extending northward into Lawrence and Elliott Counties, and southward to Floyd County and southeastward possibly into Pike County. An intelligent delineation of this structure developed the location of the Mine Fork Dome and the Laurel Creek Dome in Johnson, Magoffin and Lawrence Counties. Later a number of other small radiating structures were defined.

A study of the sub-surface stratigraphy of the Eastern Coal Field, both in the record of "wild cat" wells, and on the outcrop to the northwest, resulted in an enumeration of the following oil and gas sands:

Pennsylvanian System.
Beaver,
Horton,
Pike.

Mississippian System.
Maxton,
Big Lime.
Big Injun.
Weir,
Berea.
Devonian System.
Ohio Black Shale,
Corniferous.
Silurian System.
Clinton.
Ordovician System.
Sunnybrook.
Trenton.

As the first rigs were moved up to their location on the structures of the Johnson and Magoffin County field in 1917, particular attention was given to the sands which might reasonably be considered productive. Geologists of ability, who were at work upon the problem, eliminated the Pottsville sands (productive in Floyd County), since they were exposed in the vicinity of the major structure. The Maxton (productive in Floyd County) was regarded as too shallow, and the Big Lime was considered a doubtful producer, due to the fact that in that locality it was not definitely known to carry an intercalated reservoiring "sand."

The Big Injun was regarded as a distinct possibility, as was some unnamed sand in the upper Waverly (Mississippian). This anticipated sand did produce, and is now called the "Weir." The Berea (Mississippian), the Corniferous (Devonian), and the Clinton (Silurian) were also considered possible producers Of these three, the Corniferous received the most anxious attention, only to be disregarded entirely a little later. The Sunnybrook and Trenton (Ordovician) were from the first regarded as too deep to be of commercial importance, when considered with respect to the small amount of oil which they might be expected to produce.

A number of test wells were drilled on and off structure during 1917 and 1918. Gas was discovered in many of these wells in the Weir sand, and small amounts of Berea oil were found in others. The Bedrock Oil Co. drilled in the first gasser on the Mine Fork Dome in Johnson County in October, 1917. It produced a measured 1,250,000 cubic feet open flow at the casing head. Other gassers followed on the Laurel Creek

Dome, and these two structures became widely known as gas producers. Drilling at various points in the Big Sandy Valley had been going ahead without much success for about two years when with hardly a ripple of preliminary excitement the first real oil well was brought in on the southwestern flank of the Mine Fork Dome on the Milt Wheeler lease by the Bedrock Petroleum Company July 8, 1919. This well had an original natural production of 24 barrels and actually opened the field.

With the discovery of oil in paying quantities and quality, oil men everywhere turned their eyes toward the Big Sandy Valley. As a result of the drilling campaign which naturally followed, there have been outlined two Weir sand pools (Mine Fork and Keaton Fork) in Johnson, Magoffin, and Lawrence Counties, and four Berea sand oil pools (Paint Creek, Busseyville, Fallsburg, and Louisa) in Johnson and Lawrence Counties. In Floyd, Johnson and Magoffin Counties five large gas pools (Beaver Creek, Ivyton, Win, Red Bush, and Flat Gap) producing from the Maxton and the Weir sands have also been proven.

It is perhaps worth while in passing to remark that although the focus of geological attention from 1916 onward was principally directed upon that territory embracing the great fault zone of Johnson and Martin Counties, the upper reaches of the valley were not neglected. The writer, who first set foot "up Sandy" at Prestonsburg April 22, 1917, concerned himself principally with the geology of Floyd County and regions immediately adjacent. On the waters of Middle Creek and upper Abbot Creek the southeastward plunging axis of the important Paint Creek Uplift was outlined, while in Beaver Valley the Turkey Creek and the Wilson Creek domes and other nearby structures including the synclinal basin at the south of the Saltlick were mapped in reconnaissance. A few scattered indexing gas wells were located and measured. Later these individual maps and production statistics exhibited as a formal report by the City of Louisville in its case against the Louisville Gas and Electric Co., in the fall of 1918 and the spring of 1919, gave a decisive verdict to Kentucky's metropolis. These geologic data thus forced the rapid and significant development of the vast natural gas resources of the upper Big Sandy Valley now in

progress. Time alone, of course, can tell but it has been the writer's opinion that the value of the natural gas produced in Floyd County and the nearby upper waters of the Sandy River will ultimately greatly exceed the value of all of the petroleum produced in this watershed below East Point.

While oil and gas producers during the last two years have slowly come to realize that these new Eastern Kentucky pools are among the best in the Southern Appalachian region, the oil production in the other pools of Kentucky, with perhaps the exception of Warren County, has steadily declined. During this time the oil production of the Big Sandy Valley has steadily increased, until today the new pools are contributing approximately 175,000 barrels per month, valued at $370,000.00. The total open flow volume of the natural gas in this region is now conservatively estimated at 138,000,000 cubic feet per day. Of this huge amount, the value of the fraction of consumption is about $50,000.00 per month. These figures added to those of oil valuation amount to $420,000.00 per month, or in round numbers about $5,040,000.00 for the year 1922. Practically all of this large amount is new wealth, created within the last few years without disturbing any of the established industries of the region.

The oil and gas development of Eastern Kentucky has, in the light of these figures, at last become a real factor of prosperity, contributing to the happiness of tens of thousands, including many, indeed, who are neither directly interested at all, nor aware of the large benefits they actually enjoy. For the discovery and development of these new oil and gas pools full credit may justly be given to a few enterprising young geologists who blazed the way for drilling rig and pipe line. It is with genuine pleasure that the writer recounts his active association in the field with Raymond S. Blatchley, Mortimer A. Sears, J. S. Hudnall, Iley B. Browning, Phillip S. Russell, E. O. Rhodes, K. D. White, and one or two others, who with patience and infinite care worked and reworked the structural geology of the Big Sandy Valley.

Old Capitol,
Frankfort, Ky.
April 26, 1922.

VIII

THE OCCURRENCE OF CRETACEOUS SEDIMENTS BETWEEN CUMBERLAND AND TENNESSEE RIVERS IN WESTERN KENTUCKY*

One of the most important and unexpected results of economic studies of the sediments of the west Tennessee River valley, made two or three years ago by Wade,[1] was the final assignment of Upper Cretaceous age to certain gravels extending more or less continuously northward from the Waynesboro Quadrangle through central Stewart County, Tennessee, into Trigg County, Kentucky. Prior to this time the age of these gravels, which rest on a much eroded platform of Mississippian limestones, had been greatly in dispute. They were regarded by some geologists as of Tertiary age, having been indicated as younger than the Cretaceous by Safford.[2] At least one prominent text book[3] on geology, however, had referred them to the Cretaceous and had so indicated them on a small outline map. But Miller holding to the older view in his recent work[4] on the geology of Kentucky, denotes these deposits as belonging to the LaFayette and hence Pliocene in age. Stephenson in his discussion[5] of the Cretaceous-Eocene contact of this region ignored them entirely, following the course of Willis, who, in his monumental work on the stratigraphy of North America,[6] marks the lower Upper Cretaceous as absent in Kentucky.

In 1919, Berry produced his monograph[7] which extended the Eutaw and Tuscaloosa formations undifferentiated through Trigg County to a point slightly across the Lyon County, Kentucky, line. The basis of this determination was almost entirely paleobotanical whereas that of former investigations had

---

*Transactions Kentucky Academy of Science, Vol. I, pp. 81-83, 1924.

[1]Wade, Bruce, Gravels of West Tennessee Valley, Tenn. Geol. Survey, The Resources of Tennessee, Vol. VII, No. 2, p. 61, April, 1917.

[2]Safford, James M., Geology of Tennessee, Genl. Geol. Survey, pp. 434-438, 1869.

[3]Chamberlin, T. C., and Salisbury, R. D., Geology, Vol. III (Earth History), pp. 140-141, Henry Holt & Co., New York City, 1907.

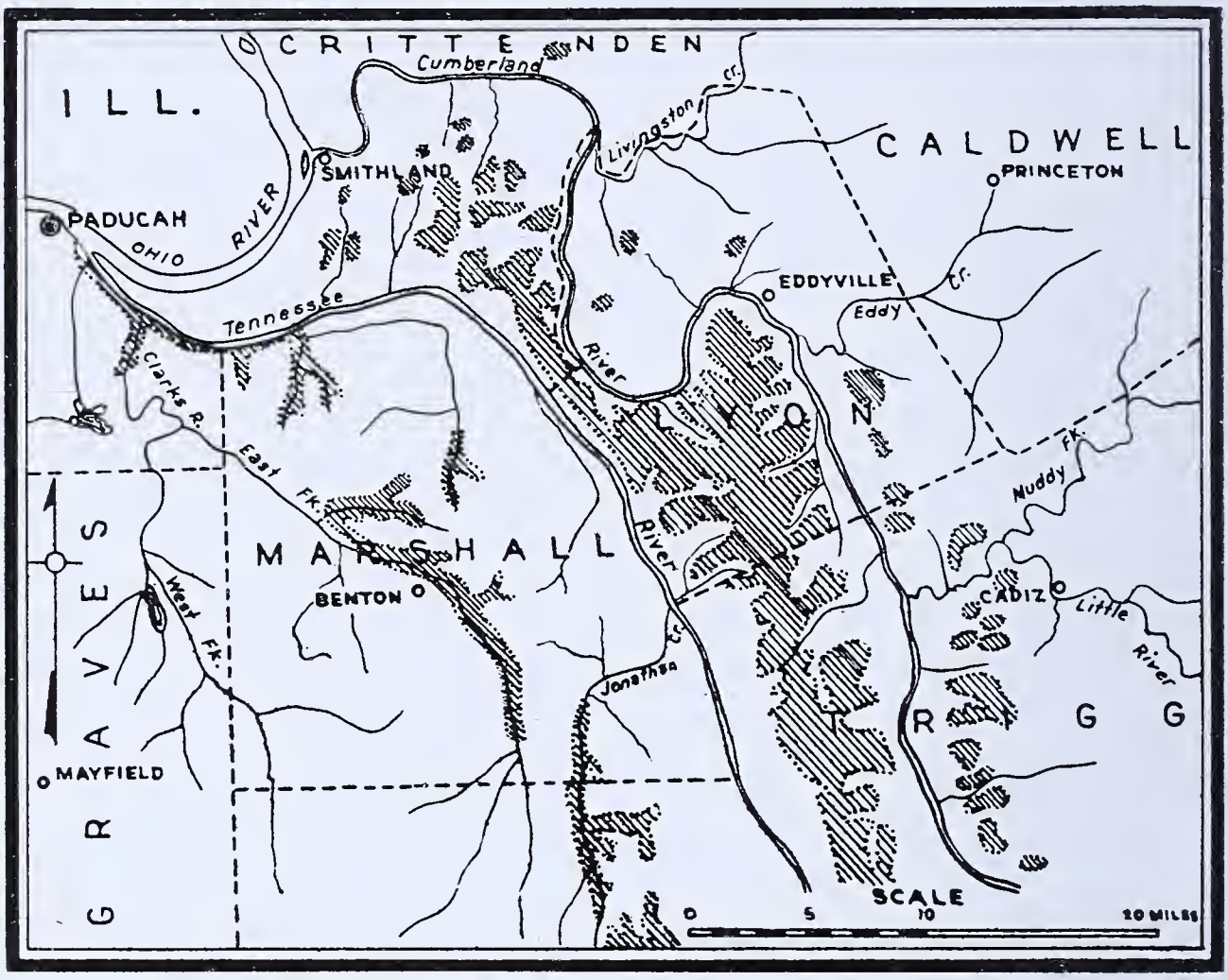
[4]Miller, Arthur M., Geology of Kentucky, Dept. of Geol. and Forestry of Kentucky, Series V, Vol. II, pp. 168-169, Frankfort, 1919.

[5]Stephenson, Lloyd William, The Cretaceous-Eocene Contact in the Atlantic and Gulf Coastal Plain. U. S. G. S., p. 99-J, and geologic map, p. 157, 1915.

[6]Willis, Bailey, Index to the Stratigraphy of North America, U. S. Geol. Survey, p. 71, and geological map, pp. 654-660. Chart of Correlations opp. p. 654, Washington, 1912.

[7]Berry, Edward Wilber, Upper Cretaceous Floras of the Eastern Gulf Region in Tennessee, Mississippi, Alabama and Georgia. U. S. Geol. Survey, Prof. Paper 112, pp. 13 and 31, and attached geologic map, 1919.

been to a considerable degree lithological, the takeoff having been in the latter case from deposits of known Cretaceous age within the limits of the Waynesboro Quadrangle.[8] Within the present year further studies[9] of the sands and gravels resting on the Mississippian platform of this portion of the west Tennessee River valley indicate the probable differentiation of the Eutaw sands and laminated clays from the subjacent Tuscaloosa gravels in Trigg County, Kentucky, and, further, the oc-



CRETACEOUS SEDIMENTS IN WESTERN KENTUCKY
The outcrop is shown by oblique shading.

currence of laminated sands and clays of Eutaw age in the vicinity of Riverview, a point some five miles above Paducah on the Tennessee River in McCracken County, Kentucky.

During the fall of 1919, and early spring of 1920, the writer in the course of a general reconnaissance of a part of Western Kentucky found occasion to traverse that section lying between the Cumberland and Tennessee Rivers from Grand River southeastward across southwestern Lyon and Trigg Counties

[8]Miser, Hugh D., Mineral Resources of the Waynesboro Quadrangle, Tennessee. Tenn. Geol. Survey, Bull. 26, 1921.

[9]Wade, Bruce, Recent Studies of the Upper Cretaceous of Tennessee Tenn. Geol. Survey, Bull. 23, p. 58, 1920.

into Stewart County, Tennessee. Particular attention was given to the position and character of the deposits of sands and gravels. Some localities referenced in the literature were visited and lithological and altitudinal comparisons were made. It was found that certain persistent gravels of this region, sometimes conglomeratic, exhibiting generally well rounded quartz pebbles and not infrequently subangular cherty pebbles, checked closely with those which were regarded as belonging to the Tuscaloosa formation in Stewart County, Tennessee. Above these gravels certain deposits of sands and thin laminated clays occur at isolated points. These seem to be similar to the sands of Stewart and adjoining counties which have been referred to as the Eutaw formation.

If these comparisons be accurate, the Upper Cretaceous is represented in Lyon and Trigg Counties, Kentucky, by remnants of these two basal members of the Upper Cretaceous, the Eutaw and Tuscaloosa formations. Taken together these sediments cover a considerable area "in between the rivers" extending as outliers in a northwest direction, possibly as far as the Ohio River. While the lack of good topographic and county base maps for the entire area involved has rendered a comparative determination of the age of these unconsolidated deposits difficult, and to a degree uncertain, it has not operated to obscure the importance of the northeast extension of these Cretaceous sediments into Western Kentucky. Assuming that these sands and gravels are a unit erosional outlier their thickness and relatively high topographic position plainly indicate a former broad and continuous extension of the Upper Cretaceous lagoonal sea to the northeastward in Kentucky, possibly as far as the periphery of the western coal field. This being the case, the northward migrations into Kentucky of the Cumberland and Tennessee Rivers over Upper Cretaceous sediments for whatever structural or other causes, must have been effected subsequently to the uplift of these sediments during Tertiary time, probably since the withdrawal of the marine waters of the Eocene.

Presented before
Kentucky Academy of Science
May 8, 1920, Lexington, Ky.

IX

NEST OF SINKING STREAMS*

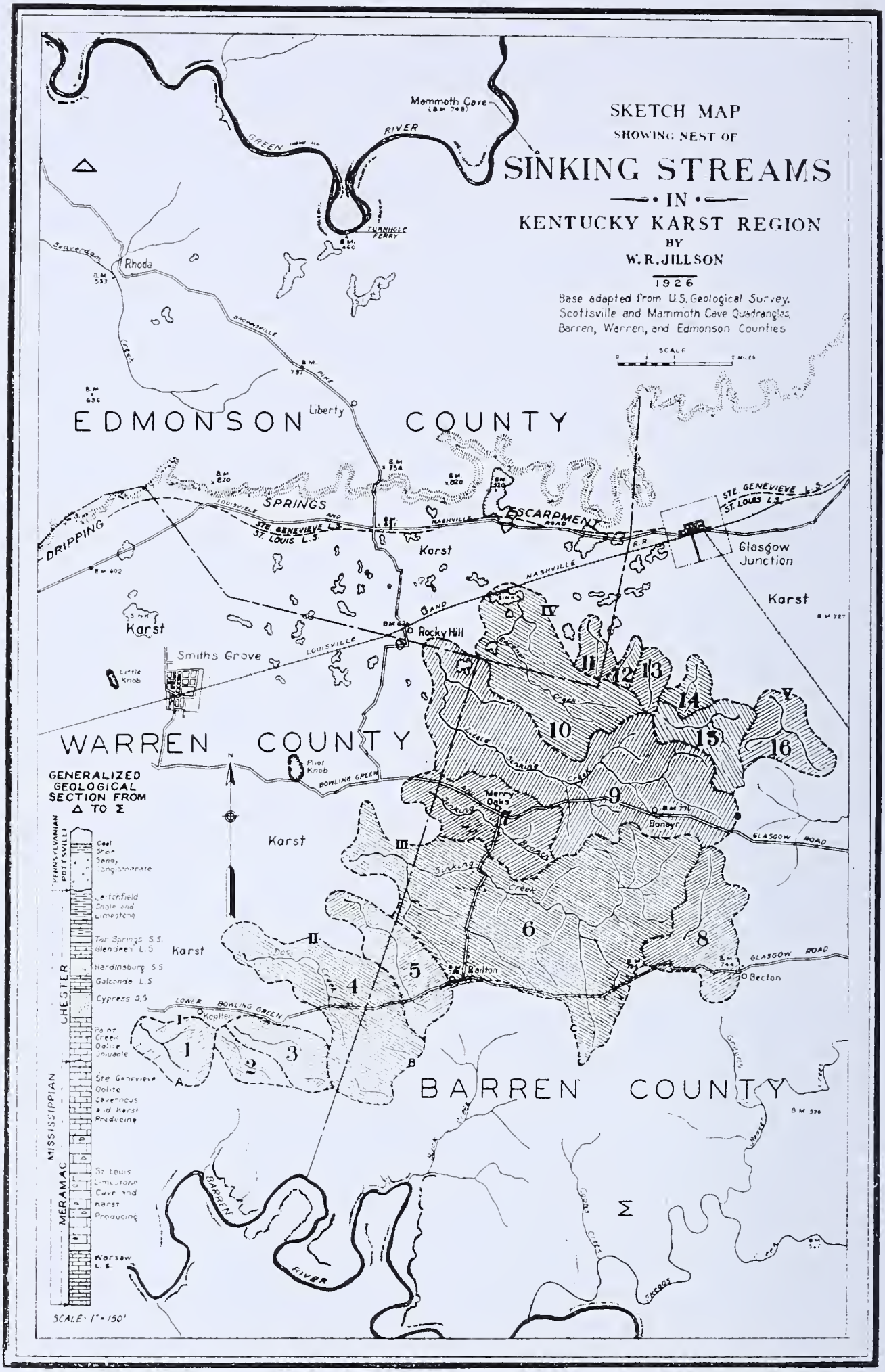
Unique physiographic features are always of expectant interest to the geologist and engineer. Their character is none the less absorbing to the layman, who, although he may not decipher the cause quite as quickly, is usually quite as generous in his appreciation. Within the broad limestone belts of northern central, southern, and western Kentucky, solution has carved into the landscape many unusual topographic forms. This is particularly the case in the type Karst country of America[1] which follows so closely the middle upper waters of the Green River.

In this region the soft and highly calcareous Ste. Genevieve and St. Louis limestone, thickening to upwards of 600 feet, are known locally as the Mammoth Cave formation. The normal dip of the region is to the northwest from the saddle between the Jessamine and Rutherford domes of the Cincinnati arch into and under the western Kentucky coal-field. Here nature has established ideal conditions for the development of erosion by solution and fill. Sink-hole topography stretches for miles in every direction between Munfordville, Bowling Green, and Franklin. These "goose nests," as they are referred to by the natives, are frequently so common, particularly in the heart of this unique area, that in traversing the countryside afoot, by automobile, or by railway train, the traveler passes from one to another again and again without encountering any well defined, or continued, surface-drainage channels. It is at once the delight of the tourist and nature-lover, and the bane of the topographer and highway engineer. A close check of some recently completed topographic sheets in this vicinity reveals not less than 4,500 separate and distinct sink-holes, highly localized outlets for surface drainage. The great Sub-carboniferous limestones underlying this type-region, as well as those of similar physiographic figure adjoining, must be literally honeycombed with intercepting subterranean channels of solution.

Well within this Karst region, though extending southeastward to its border, is an area on the south sufficiently exceptional

---

*Pan-American Geologist, Vol. XLVIII, pp. 343-345, December, 1927.
[1]Pan-American Geologist, Vol. XLII, August, 1924.



MAP OF SINKING STREAM COUNTRY

to merit individual consideration. Here, between Glasgow Junction and Smiths Grove, stations on the Louisville and Nashville railroad, in Edmonson, Barren and Warren counties, the writer, in the course of recent field investigations, has encountered a group of sixteen short, surficial streams, the lost headwaters apparently of the ancestral Beaver Dam Creek, a northwestwardly flowing tributary of the master-stream of this midland country, Green River. Sinking streams are not unusual in Kentucky, or many other parts of the world, but a "nested" group of sixteen separate streams adjacent in their headwaters and a unit geographically is sufficiently unique to give the physiographer delight and the geologist pause. The recent completion of topographical surveys of this region has brought out sharply on the Mammoth Cave and Scottsville sheets the areal extent and figure of this group of unique streams, a sketch of which is attached. "The nest" is roughly triangular, the hypothenuse, or headwaters base-line, north 60 degrees east, being about 13 miles in length. The streams flow northwestward generally from this dividing ridge, with one notable exception, along somewhat parallel lines of channel drainage averaging north 30 degrees west. The greatest of these streams, Sinking Creek, has a length of 6½ miles and a drainage basin of about 20 square miles, while several of the smaller ones are less than a mile in length, and some of these drain considerably less than a square mile in area. About 40 square miles is covered by the entire group.

The average elevation of the dividing ridge bounding "the nest" of sinking streams on the southeast is 750 feet A. T., though maximum elevations of 800 feet are indicated. The general relief within the sinking-stream area is about 210 feet, although Sinking Creek itself exhibits a maximum individual relief of 240 feet, while some of the minor streams show as little relief in their entire courses as 110 feet. The streams in this group all fall into sink-holes with frequently outcropping St. Louis (Carboniferous) limestone ledges at their lower extremity. None of them ever reappear at the surface in this locality, although, of course, merged with other Karst drainage and following diverse uncharted cavernous courses, this water finds its way eventually to Green River at some unknown

point below Mammoth Cave, probably in the vicinity of Brownsville. In this part of the deeply entrenched channel of the Green River there are a number of rather considerable tributary subterranean streams on the southeast side, the clear waters of which may occasionally be seen joining the frequently turbid master-stream at the base of great gray cliffs of Mississippian limestone.

Old Capitol,
Frankfort, Ky.

X

THOUGHTS ON EVOLUTION*

Find tongues in trees, books in the running brooks, sermons in stones, and good in everything.—Shakespeare.

Let the ignorant and uninformed deny it whenever or wherever they will, the fundamental principles of organic evolution are indisputable. The invertebrate paleontologic record from the Cambrian to the Pleistocene presents tens of thousands of absolute proofs. The vertebrate paleontologic record from the Devonian to the present dovetails into the record of lower animal life with thousands of proofs. The paleobotanical record from the Pennsylvanian to the present acts as a complement, and adds literally countless thousands of undeniable proofs of the existence of evolution as a natural law. The great sciences of geology, biology, and botany afford to him who has the intelligence and patience to read their God-made record in the field—not in the library—hundreds of thousands of simple and certain proofs of the basic principle of the continuity of life with change on this earth from times infinitely remote.

The fundamental principles of evolution do not need to be defended. Of co-ordinate value with elemental truths, they are above argument. They are as established and quite as far beyond the possibility of human alteration as are the strong tides of the ocean, the flight of the precious years, or the distant idiosyncrasies of a comet's tail. From an educational standpoint, however, evolutional truths are essential to a broad, rational, and intelligent understanding of this earth and its inhabitants. Honest, though misguided, attempts to cripple the intellectual usefulness of evolutional truths merit the stern rebuke of public opinion.

The ridiculous, yet seriously contemplated, moves of certain richly subsidized affiliated church organizations to prohibit by statute, and define as ungodly by clever propaganda, the teaching of human or other evolution in the public schools of Kentucky will not provoke any particular anxiety on the part of evolutionists. The leading educators of our country, however,

*The Lexington Herald (Ky.). No. 39, p. 5, February 8, 1922.

who recognize the truth and value of evolution may become alarmed, and Kentuckians generally who love their State and its traditions will sooner or later resent in no uncertain terms the arrogant persecution of intellectual freedom. Could the fact be made plain that evolution cannot be destroyed in principle by statutory enactment or otherwise, what intellectual mortification and chagrin might be spared Kentuckians. The natural world recognizes in evolution a governing law, and will proceed about its affairs quite oblivious of the admonition of man. Many will recall the story of that great and powerful English king who once stood on the seashore and commanded the tides to stand back, but history does not tell of their retreat.

Man's control of the elements is relatively slight. But his attempted control of public opinion has not infrequently accomplished great things, many of them modern miracles of retroaction. The serious criticism a few days ago by a Kentucky daily newspaper of the low moral tone of a new book of fiction resulted, among other things, in selling the entire edition allotment of the local book stores in a single day. With everything to damn it, the whiskey traffic of this country, only a man-made institution, has died hard, for the principle of suppression has operated to give it life—post mortem. Statutory enactments against educational and mental freedom in America, and in Kentucky especially, where the pulse of personal liberty has ever been strong, will not only be found unconstitutional by every court, but will in reality operate to incite widespread and popular interest in the subject banned. The poet Bryant wrote: "Truth crushed to earth shall rise again." Certainly there should be no surer way of advertising and urging a study of evolution by the American people generally than by withdrawing it from the curriculum of the schools.

It is recognized, however, that much of the popular resentment against the teaching of evolution is undoubtedly justified. It is claimed that the old-time religious faith of the youth is broken and nothing put in its place but cold materialistic conceptions. Too frequently this is too true. But the fault is not with the principles of evolution; it is in the teaching of vague, unsound principles. There is nothing more dispassionately true in science than the bare principles of evolution as read

from a book. There is nothing more real and romantic in science than the colorful presentation of the actual record of evolution as read from the rocks, and seen in existing life. Such interpretations unadulterated by generalized philosophies and unsolvable inquiries into ultimate origins, only serve to strengthen the basic religious convictions of the student.

Christ-like attitudes and broad evolutionary understandings are not incompatible. Jesus said: "Ye shall know the truth, and the truth shall make you free." (John 8: 32.) It is a demonstrable fact that the foremost evolutionists of America are good and godly men, highly respected in their communities and by the world. Would that all of our Kentucky youth were more like them, as high in their ideals, as broad and useful in their role of service, and as upright and as Christ-like in their physical and mental relations to themselves and to mankind.

Old Capitol,
Frankfort, Ky.

XI

VALLEY-FILLED AREAS OF THE WESTERN KENTUCKY COAL-FIELD†

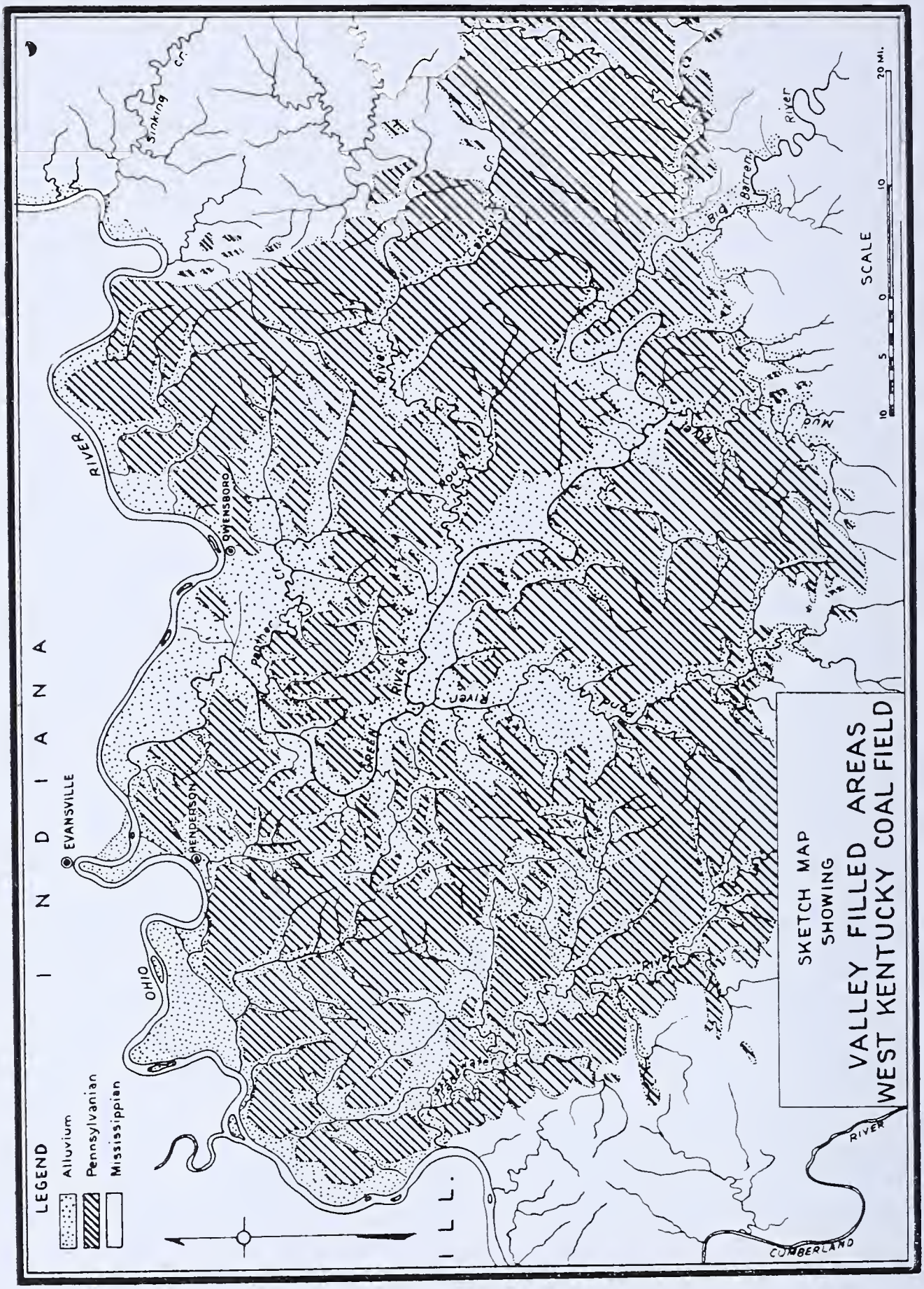
Regional depression in Western Kentucky has been recognized by geologists and physiographers for many years. Areal reports on small geographic units in this part of the State have discussed in more or less detail local alluviation. The completion of the topographic map of the Western Kentucky coal field during the past year makes possible now for the first time a unit consideration of the entire region. Surface elevations ranging from 350 feet to about 750 feet are general. Summit levels of this maturely eroded plateau range from 650 to about 800 feet above sea-level.

Observations in the field coupled with critical cartographic computations indicate that in a physiographic-geologic basin which is essentially coincident with the Western Kentucky Coalfield, but encompassing some out-of-the-State extensions to the north there are 2,050 square miles sufficiently depressed on a regional basis to allow of valley-filling. The significance of this alluviated area is quickly grasped when it is remembered that Kentucky's western coal field contains only about four and a half thousand square miles. Within this carboniferous province the range of flood plain elevations varies from 350 feet at the juncture of the Tradewater and Ohio Rivers to 425 feet on the tributaries of the Tradewater and the Green Rivers, the major interior drainage courses. Filled valleys four to eight miles wide are not uncommon. Well drillings and other mineral explorations in the Green River and Ohio River valleys point to a maximum thickness of alluvial sediments ranging up to nearly 200 feet.

Physiographic and stratigraphic criteria indicate this broad depression began about the middle of the Pleistocene. Subsequent uplift in a small degree is now quite thoroughly established at many points along the Green and Tradewater courses. This regional depression in Western Kentucky has had a very

---

†The Pan-American Geologist, Vol. XLVII, No. 4, pp. 315-316, May, 1927. Abstract presented before Sect. E, Am. Association for the Advancement of Science, Philadelphia, December, 1926.



ALLUVIATED AREAS IN THE WEST KENTUCKY COALFIELD.

decided effect upon social and economic development of the area involved. Transportation both by water and overland routes has been facilitated by low relief, but many large swampy areas are withheld from agriculture because of a lack of good drainage. Coal outcrops are few, though where found are frequently easily stripped. Drift mining is almost unknown. Mineral springs are only occasional, and oil and gas exploration is attended by indifferent success in all unproven alluviated areas.

Old Capitol,
Frankfort, Ky.

PART TWO

Sketches in Other Fields

I

THE VOLCANIC ACTIVITY OF MOUNT ST. HELENS AND MOUNT HOOD IN HISTORICAL TIME*

Not a little has been written in one form or another concerning the prehistoric and recent activity of those splendid volcanic cones of the Cascade Mountains which stand like sentinels on guard at the gateway of the Columbia River. Mount St. Helens (9,750 feet) in Washington is about forty miles north of the Columbia, and Mount Hood (11,225 feet) in Oregon is about twenty miles south. By reason of their dominant size (Vancouver reported Mount Hood to be 25,000 feet high), their beauty, and their relative position, these mountains have been called the "Guardians of the Columbia." About their magnifi-

DESOLATE UPLAND SLOPES OF MT. ST. HELENS
At an elevation of 7,000 feet shown here, lava capped ridges and glacier filled valleys alternate.

cent, perpetually snow-clad peaks is woven a wealth of legend and description, which antedates the arrival to this North Pacific coast of the first intrepid Spanish and English explorers.

Perhaps the most unreliable, though not the least picturesque, source of information concerning the activity of these old volcanoes is to be found in the tradition and tribal lore of the Puget Sound, Columbia River, and coastal Indians. These primitive peoples, after nearly a century of contact with civilization, still speak with mingled awe and reverence of the "Fire Mountain" (Mount St. Helens) and the "Mountain That Was God" (Mount Ranier). Captain J. C. Fremont in his explor-

*Geographic Review, June, 1917, pp. 481-485.

ation camp on the Columbia River on November 27, 1843, wrote in his diary[1] with respect to Mount Hood and Mount Jefferson, the next prominent volcano to the south, "The Indian superstition has peopled their lofty peaks with evil spirits, and they have never yet known the tread of a human foot." The original diary of Lewis and Clark,[2] who reached the mouth of the Columbia in December, 1805, also alludes to this characteristic superstition. It does not refer, however, to volcanic activity in either Mount St. Helens or Mount Hood. S. F. Emmons in a report on "The Volcanoes of the Pacific Coast of the United States" says:[3]

"Even our half-civilized Indians of the Northwest, in spite of their association with the white man, cannot be induced, by hope of reward or fear of punishment, to approach the snow-covered peaks in their midst, whose actual manifestations of volcanic energy must exist in their minds as dim traditions."

The first authoritative reports of volcanic activity of these Columbia River volcanoes come from the same source. A little farther on[4] Emmons says:

"Mount St. Helens, on the other hand, is remarkable for its regular conical shape. It is . . . the only peak of which I was able to get a definite account of an eruption. I was told by an old French Canadian voyageur, formerly in the employ of the Hudson's Bay Fur Company, that St. Helens was in active eruption in the winter of 1841-42. To use his expression, the light from the burning volcano was so intense that one could see to pick up a pin in the grass at midnight near his cabin . . ."

Captain Fremont, again, writes[5] under the date of November 13, 1843:

"Wherever we came in contact with the rocks of these mountains, we found them volcanic, which is probably the character of the range; and at this time, two of the great snowy cones, Mount Regnier (Mount Ranier) and St. Helens, were in action. On the twenty-third of the preceding November (Nov. 23, 1842),

---

[1]Report of the Exploring Expedition to the Rocky Mountains in the year 1842, and to Oregon and North California in the years 1843-44, Office of Explorations and Surveys, War Department, Washington, 1845; reference on p. 199.

[2]Original Journal of the Lewis and Clark Expedition, 1804-1806, edit. by R. G. Thwaites, 7 vols., and atlas, New York, 1904-05; reference in Vol. 3.

[3]Jour. Amer. Geogr. Soc., Vol. 9. 1877. pp. 45-65; reference on p. 45.

[4]P. 53.

[5]Op. cit., pp. 193-194.

St. Helens had scattered its ashes, like a light fall of snow, over the Dalles of the Columbia, 50 miles distant. A specimen of these ashes was given to me by Mr. Brewer, one of the clergymen at the Dalles.''

Evidence in corroboration of this statement and date is to be found in various sources, the most authoritative of which is the following. The Rev. J. L. Parrish, of Salem, Oregon, writing in Steel Points, a Portland (Ore.) mountaineering quarterly magazine, says:[6]

MT. ST. HELENS—GEM OF CASCADE TOPOGRAPHY

''. . . On the 22nd day of November, 1842, I was in the old Mission house, ten miles below Salem, with several other missionaries. . . . I stepped outside and noticed the eruption of Mt. St. Helens. . . . We saw arising from its summit immense and beautiful scrolls . . . of steam. Then came a stratum just below . . . which was an indefinite gray. Then down next the mountain's top the substance emitted was black as ink. The next day . . . I noticed that she (Mount St. Helens) had changed her snowy dress of pure white for a sombre black mantle. The ashes fell at the Dalles to the depth of half an inch. . . . The eruption was on the south side of the mountain about two-thirds of the distance from the bottom to the top.''

About sixty miles to the south of Mount St. Helens and just

[6]Vol. I, No. 1, pp. 25-26.

across the Columbia River stands the picturesque cone of Mount Hood, the "Pride of Portland." Geographically and geologically its history is linked with that of Mount St. Helens as well as with a number of lesser associated peaks. Its volcanic activity may be traced (if signed reports published in Oregon and Washington newspapers and periodicals may be relied on) to a much more recent date than that of its sister mountain. W. F. Courtney, of Walla Walla, Washington, writing of activity in Mount Hood in the *Everett* (Wash.) *Record*, May 17, 1902, says:[7]

"The eruption took place during the latter part of September, 1859. . . . We were camped on Tie Ridge about thirty-five miles from Mount Hood. . . . It was about 1:30 o'clock in the morning . . . when suddenly the heavens lit up and from the dark there shot up a column of fire. With a flash that illuminated the whole mountainside with a pinkish glare, the flame danced from the crater. . . . For two hours, as we watched, the mountain continued to blaze at irregular intervals, and when morning came Mount Hood presented a peculiar sight. His sides, where the day before there was snow, were blackened as if cinders and ashes had been thrown out."

Under the title of "Eruptions of Mount Hood" the weekly *Oregonian* (Portland) of August 20, 1859, says in part:[8]

"On Thursday night the fire was plainly seen. . . . Yesterday the mountain was closely examined, when it was seen that a large mass of the northwest side had disappeared. . . . . The dense cloud of steam and smoke constantly rising over and far above the summit, together with the entire change in its appearance heretofore, convinces us that Mount Hood is now in a state of eruption, which has broken out within a few days."

The most recent recorded activity of Mount Hood occurred September 21, 1865. The *Oregonian* of September 26, 1865, says in part:[9]

"It is some time since we have had an excitement about Old Mount Hood belching forth, but on Saturday last the active puffs of dense black smoke were witnessed by hundreds of people in this city."

Farther on[9] it prints a letter from a John Dever, Company E,

---

[7]Quoted in Steel Points, Vol. I, No. 3, p. 135.
[8]Quoted in Steel Points, Vol. I, No. 3, p. 136.
[9]Quoted in Steel Points, Vol. I, No. 1, p. 23.

1st Regiment. Washington Territory Volunteers, written at the Vancouver, Wash., barracks, where he was a part of the guard in the early morning of June 21, 1865:

". . . Judge, then, of my surprise to see the top of Mount Hood enveloped in smoke and flame . . . accompanied by discharges of what appeared to be fragments of rock, cast up a considerable distance, which I could perceive fell immediately with a rumbling noise not unlike distant thunder. This phenomenon was witnessed by other members of the guard. . . ."

The probability of the genuineness of these and similar statements will not be questioned by anyone who is familiar with the geology and the physiography of Mount St. Helens and Mount Hood. Each of these mountains is a beautifully symmetrical cone, the higher elevations of which are only slightly scarred by steam and glacial erosion. Mount Hood is the more sharply pointed, owing to the loss of a part of the crater rim. Both mountains show toward their bases well-developed lateral drains, choked with lava flows, minor vents, and "blow holes." In many cases these flows present a most strikingly recent appearance, with bright, new, and strongly outlined surfaces, neither aggraded nor degraded, and barren of any vegetation except the scantiest.

Various travelers, prospectors, and United States army officers who penetrated into the primeval forests of this northwest wonderland have noted these things, and each one has brought back his own story. Lieut. C. P. Elliott, U. S. A., after exploring Mount St. Helens, made a rough reconnaissance topographic map of the area.[10] He noted the choking and damming of the lateral drains and speaks in particular of two instances which have a present bearing. The first one is that of a drain into the Kalama River, where the lava dam has formed the beautiful Lake Merrill (called "Trout Lake," by some), which is unique in that it has no surface outlet and appears never to have had one.

Speaking of this lava dam he says: "Further to the north and toward the Kalama River, where the lava flowed over the standing trees (the places of the trunks now forming wells in the lava), running water can be heard." Russell, in his "Vol-

[10]Mount St. Helens, with map, 1:180,000, Natl. Geogr. Mag., Vol. 8, 1897, pp. 226 230.

canoes of North America,''[11] notes that Mount St. Helens, which was ascended as early as 1889, ''seems to have been active in recent years, and is fresher in appearance than Mount Hood.'' He also refers to the lava-damming of Lake Merrill, the lava tree casts, the still active ''fumaroles,'' and the recent ''blow holes'' on the long lava flow on the southwest side of the mountain. Lieutenant Elliott has referred[12] to this lava bed, which finds its origin somewhere near Butte Camp at an elevation of 4,500 feet, and flows and cascades down a number of old valleys for nearly ten miles to the Lewis River, where it terminates in a number of large conical ''blow holes'' at an elevation of 1,000

RUGGED TOPOGRAPHY ADJACENT TO MT. ST. HELENS

feet. Its principal course lies between Cougar Creek and Big Creek, mainly in two large drains, one of which supplies the underground water for Lost Creek. Incidentally this superb lava flow is chiefly notable throughout the Northwest for its great cave over a mile in length and one of the largest of its kind in North America.[13] This flow has been identified as the one referred to by Fremont, Parrish, and Emmons as being active on November 22, 1842, and also possibly in 1841.

The summer of 1915 was spent by the writer in studying in the field the geology and physiography of Mount St. Helens and

---

[11]New York, 1897, p. 241.
[12]Ibid., p. 228.
[13]The Lava Caves of St. Helens. Mazama, Vol. 2, 1900-05, pp. 134-135.

its environs. On August 5, 1915, the summit was reached after a hard two hours' climb from Butte Camp. Previous to this, three weeks had been spent at an elevation of 4,000 to 7,000 feet, where many evidences were found of recent mild eruptions. Among other things of interest disintegrating charcoal and wood fibre in one of the horizontal lava tree casts in the great flow of the southwest side of the mountain were discovered. This evidence is made the subject-matter of another paper, "New Evidence of a Recent Volcanic Eruption on Mount St. Helens, Washington."[14] The importance of this discovery was anticipated by J. S. Diller, who speaks[15] at length as to the value of these lava tree casts. His deductions, made from a resume of the better known literature, are that mild eruptions of diminishing strength and duration have most likely occurred on Mount St. Helens within the last century.

In conclusion it seems worth while to call attention summarily to the following facts. The separate and unrelated reports and statements of Fremont, Emmons, and Parrish fix without question the date of November 22, 1842, as one of considerable volcanic activity of an eruptive and extrusive nature on Mount St. Helens. The reports of Diller, Elliot, and others establish without doubt the recency of such volcanic activity. In consideration of the charcoal and wood fibre in the lava casts it may be that the last ebbing tide of extrusive volcanism of Mount St. Helens continued on in a feeble, localized, and intermittent way until well into the third quarter of the nineteenth century, as published observations have shown to have been the case with Mount Hood. In the light of this suggestion it is interesting now to reconsider casually what vital role may have been played in the lives of the early natives of this part of the Cascade Mountains at no really distant date by these two "Guardians of the Columbia."

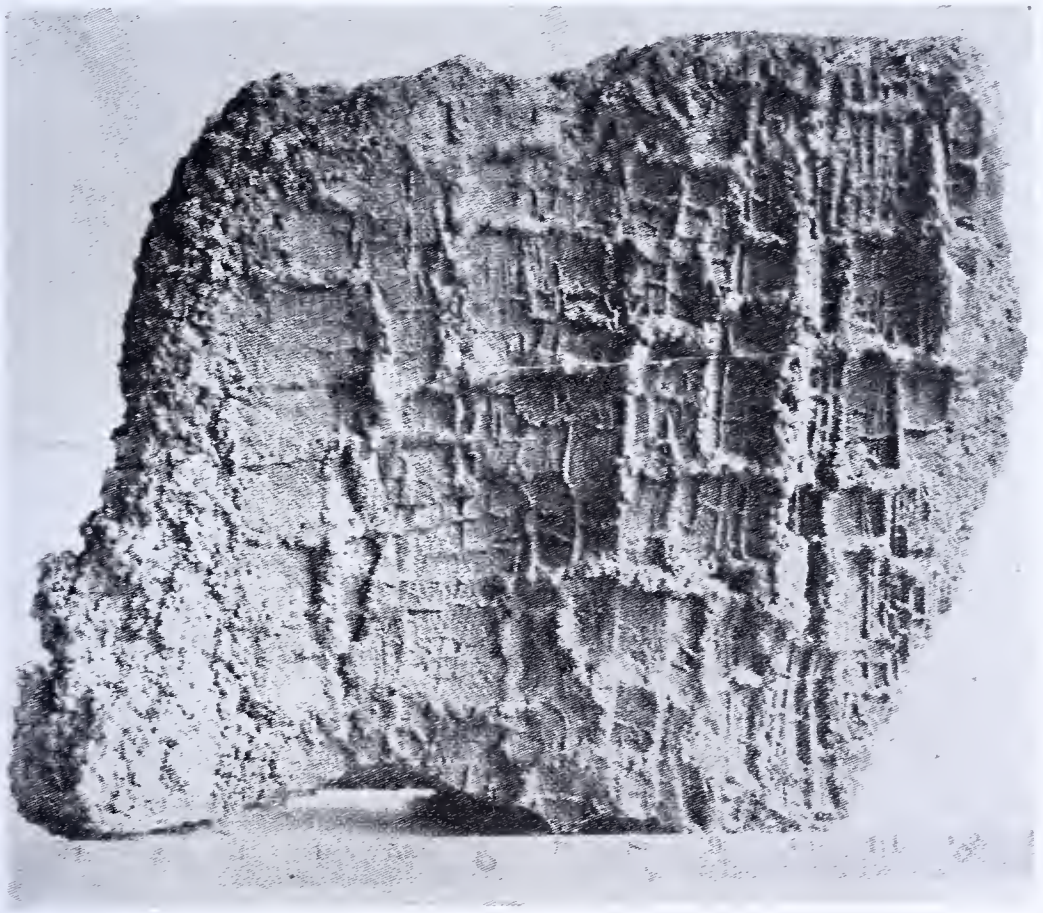
Yale University,
New Haven, Conn.

[14]Amer. Jour. of Science, in press.
[15]Latest Volcanic Eruptions of the Pacific Coast. Science, Vol. 9, 1899, pp. 639-640.

II

NEW EVIDENCE OF A RECENT VOLCANIC ERUPTION ON MOUNT ST. HELENS, WASHINGTON*

Every intelligent person returning from the wooded foothills or snow-capped summit of Mt. St. Helens, Washington (9,671 feet, U. S. G. S.) brings back stories of recent volcanic action. The tourist, though he keeps to the well-beaten, government trails, sees the evidence on every side, and if he will but listen, may still



CARBON CAST LAVA FROM MT. ST. HELENS
This specimen was deposited in Peabody Museum at Yale University.

hear from the lips of a few old pioneering guides very interesting, though perfectly unreliable, reports of "the last eruption of the mountain."

During the summer of 1915 the writer spent several weeks examining the geology and physiography of the Mt. St. Helens region, making the climb to the top on August 5th. Many recent flows were noted at elevations of 6,000 and 7,000 feet, but by far the greater masses of extrusive material lie below 4,500 feet. In September while investigating the surficial character of the

*American Journal of Science, Vol. XLIV, July, 1927.

great recent flow on the southwest side of Mt. St. Helens, between Big and Cougar Creeks, the block of lava shown in the accompanying illustration was collected. The specimen, which is now in the Yale University Geological Collections of Peabody Museum, New Haven, was taken from the surface of the flow at the end of a spur of old metamorphic rock which rises out of the floor of the flood, like an island in the sea. The spur is,

VIRGIN FORESTS OF FIR SURROUNDING MT. ST. HELENS

in effect, the lower end of the sharp divide between two old lava-filled valleys. At this point two long lava ribbons stretching down the side of Mt. St. Helens unite before cascading into the bottom of the Lewis River Canyon two hundred feet below.

In spreading out laterally at the lower end of this spur to join each other, the flows evidently became slower, and formed, if the comparison may be allowed, a "lava back-water." From the standpoint of the physical principle involved, the condition found here must have been essentially the same as that which is seen to be operative at the foot of any stream island. The slackening of the lava flow is obvious, for the surface consists of a series of roughly outlined terraces leading down from both main flows into a considerable depression which finds its greatest depth close to the spur-end. As far as the preservation of the tree moulds or casts is concerned, this slowing up and thinning out of the lava has been a fortunate thing. In places where the

lava is much thicker and the flows were more rapid and more powerful, very few traces of tree casts are to be found. At the place where the specimen shown in the illustration was procured, are to be found the lava casts of a score or more of standing and fallen logs. The abundance of casts is a measure of the protection from the destructive force of the two main flows.

The occurrence of this small locality has not been mentioned before in the literature of the subject, although a number of others adjacent to the main trails have been described. The vertical casts appear like man-holes in the lava floor, "the wells in lava" of Elliott.[1] At depths of from nine to twelve feet these regularly outlined cylindrical carbonized casts of the trees extend outwards and downwards into giant root casts. The horizontal casts appear as long, regularly cylindrical lava-moulds extending back considerable, but undetermined, distance into the rock. The horizontal casts are in general of a uniform size and from two to three feet in diameter. The vertical trunk or stump casts seem to be larger (which we should logically expect), some of them attaining five feet in diameter.

The museum specimen was taken from one of the horizontal casts of this area. It shows in fine relief the longitudinal breaking or splitting of the wood, and the transverse or circumferential check rings, both of which are due to the special kind of carbonization and rapid contraction of the wood cells which the tree trunk underwent in its nearly-closed lava kiln. The fine longitudinal striae-casts show the character of the annual growth layers of the wood. The size and rough character of the largest ridges on the cast indicate that the log had been greatly charred before the lava struck it. Studies of the carbonization of the cast have led to the placing of the cast-producing tree in the conifer group. This statement finds strong support in the great diameter of the casts themselves. The size of these trees is indicated by the flatness of the arch of the section of the lava cast shown on page fifty-seven.

The important bearing of these tree casts upon the determination of the dates of the various flows is pointed out by Diller,[2] who also gives a resume of the better known literature on the

---

[1]Eliot, C. P., Nat. Geogr. Mag., Vol. VIII. p. 227. 1897.
[2]Diller. J. S.. Latest Volcanic Eruptions of the Pacific Coast, Science, N. S., Vol. LX, pp. 639-40. 1899.

subject. He publishes a letter from Mr. F. V. Coville of the Department of Agriculture, who, while studying the flora of Mt. St. Helens, found some interesting charred trees under recent gravels of the Kalama River. The following statements occur in the second paragraph of Mr. Coville's letter: "The character of the charcoal, which need not be described in detail here, is such as at first to suggest that it was made in a very carefully prepared kiln. There are, however, no charcoal pits in the region. . . . It is evident from the peculiarities of the flora of Mt. St. Helens, and from its limited erosion, that it is a mountain of very recent volcanic origin." And a little further on, speaking of the tree casts, he says, "Though I was unable to visit the places where these tree moulds occur, I talked with . . . men who had seen these casts, but none of them had seen charred bark or wood in the holes." His conclusions are, however, that these casts are the source of the peculiarly charred logs of the Kalama. Diller agrees with Coville, and says these charcoal trees are probably at least 100 years old, and, "If this be true it is probable that some of the charred logs are not the result of the last eruption of Mt. St. Helens, but an earlier one." This statement virtually amounts to a recognition by Diller of volcanic activity on Mt. St. Helens within the last century.

Of first significance then, and in line with the arguments of Diller and the suggestions of Coville, was the discovery in the same locality from which the Yale cast was taken, of the decayed and disintegrating remains of a small tree trunk. The material lay in the bottom of one of the horizontal casts and extended back into it for several feet at least. A portion of this residue, which consisted mainly of broken, powdered charcoal and a small amount of the decayed wood, was collected, but, unfortunately, was lost in packing out of the mountains.

In consideration of the fact that the temperatures of most fluid lavas are greatly in excess of the ignition point of wood, it is realized that any carbonized log producing lava-cast would have a very slight chance of being preserved, even to the end of the period of volcanic activity, unless completely imbedded within the lava. In such an event the log would be reduced to absolute charcoal, but the chances of its discovery in recent, uneroded lavas would be slight. It is thought that the only possible

means by which original spontaneous combustion could have been stopped, thus preserving the charred logs in the moulds, would be by the introduction of a completely encasing water jacket immediately following the contact of the lava with the wood. It may be noted again that the casts herein described occur in a considerable depression, which might well have been a small collecting basin for the hot and rapidly vaporizing surficial waters which commonly accompany volcanic disturbances of this kind. The rough terracing of the lava seems to indicate the existence of a rising and widening water barrier and the spur described above is favorably situated for directing surface water into a depression at its base.

The woody material taken from the lava casts has received only superficial examination. The writer, therefore, considers it inadvisable at this time to enter into further abstract considerations. If new collections and detailed studies show that this decaying woody residue was a part of the original cast-producing log, and not, as has been suggested, foreign material introduced in some way into the cast, the views of Coville and Diller regarding the recency of volcanic activity in the Cascades receive direct support. These facts, exclusive of much existing corroborative documentary evidence, would be sufficient to establish the occurrence of mild extrusive volcanics at Mt. St. Helens well within the last century.

Yale University
New Haven, Conn.

III

PHYSIOGRAPHIC EFFECTS OF THE VOLCANISM OF MOUNT ST. HELENS*

Mt. St. Helens, lying roughly midway between Mts. Ranier and Hood, is more remote and less well known than either of these peaks. The plateau from which it rises is minutely dissected and densely forested. Only two wagon roads, bad beyond description, approach the mountain fastness; none traverse it. The lower river bottom farms, rich though circumscribed, become gradually smaller and poorer as one approaches the headwaters. Lately fenced, grass-carpeted meadows, studded with neat white-painted barns and houses, give way to bushy stump-lot clearings and single-room log cabins. These in turn becoming more infrequent stand with their backs to the virgin timberland of hill and mountain side. All through the countless inner hills and valleys, beside abandoned overgrown trails and again in the most remote and inaccessible places, are found deserted cabins now moldering into ruins, the homes of former prospectors. Though indications of mineral wealth—gold, silver, and copper—sufficient to fascinate the novice may be found at every hand, the miserable failure of the region generally to respond to diligent search and commercial exploitation is only too apparent. The great forests of Douglas fir and kindred evergreens, now largely protected within the Federal Columbian Forest Reserve, stand as the greatest natural resource of economic importance. But to the state and the nation the region finds its first value as a paradise for the tourist and nature lover.

Configuration and Lines of Ascent

From an altitude at the base of about 4,500 feet the snow-capped summit of Mt. St. Helens rises to an altitude of 9,761 feet above mean sea level. The shape of the mountain is that of a symmetrical cone with crestal angles figured from the crest for the highest and last mile as follows: (1) to the southwest in the direction of Butte Camp, 31½°; (2) to the

*The Geographic Review, Vol. XI, No. 3, pp. 398-405, July, 1921.

The field work on which the data incorporated in this paper are based was done by the writer during the spring, summer and autumn of the year 1915 while he was a member of a U. S. Geological Survey field party mapping the Mt. St. Helens quadrangle.

northwest in the direction of Toutle River canyon, 27½°; (3) to the northeast in the direction of the headwaters of Smith's Creek, 23°; (4) to the southeast in the direction of the headwaters of Muddy River, 27°. Notwithstanding the fact that the angle of inclination from Butte Camp to the crest of Mt. St. Helens is, as shown above, slightly sharper, it is coincident with the trail most frequently taken by mountain-climbing tourists. The selection of this line of ascent is due principally to its accessibility. It is possible, however, as has been demonstrated, to climb the mountain from several angles.

The volcanism which found active expression as recently as the early part of the last century[1] has been responsible for the creation of a number of physiographic features which lend individuality to this old cone. Interesting as are the problems they present, these surficial peculiarities have as yet received little attention in geological and geographical literature.

Pyroclastic Deposits and Lake Formation

In the large amounts of pyroclastic materials and the succession of lava flows ample evidence may be noted of a rather extended period, or series of periods, of explosive and then quieter effusive eruptions. On the southwestern flank the headwaters of Kalama River from the vicinity of McBride Lake to below Kalama Falls have been buried under a very thick deposit of pyroclastic material, which, with other geologic agencies, probably of an intrusive nature, have operated to dam up the waters of a northwestward-flowing branch of Kalama River and form Merrill Lake. This mountain pond has an elevation of 1,533 feet, is elongate in figure, and boasts two small rocky islands, uneroded ridges in the old valley. McBride Lake, located just to the east of Goat Mountain, and one or two other smaller ponds in this vicinity were formed by the same deep deposit in which the Kalama River has cut for itself a deep, canyon-like channel.

The South Fork of Toutle River, flowing slightly to the north of west from Mt. St. Helens and fed in part by melting glacial waters, is entrenched deeply in a narrow boulder-clogged valley. There is a difference of relief of 2,500 feet from the Toutle River bed to Spud Mountain on the north and of 2,800 feet to

[1]The Volcanic Activity of Mount St. Helens and Mount Hood in Historical Time, Geogr. Rev., Vol. 3, 1917, pp. 481-485.

Goat Mountain on the south. Both headwater branches of the South Fork of Toutle River head against the western slope of Mt. St. Helens proper in very precipitous canyons gouged out of original dendritic drainage of Smith's Creek, a southeastward-fragmental debris several hundred feet deep.

Immense deposits of pyroclastic are to be found in the valley of the North Fork of Toutle River. The fill has been so general that an undulating river plain in many places over a mile in width has been developed. The river channel itself is boulder-

MT. ST. HELENS—A TYPICALLY TRUNCATED VOLCANIC CONE

choked and, like all of the streams heading in Mt. St. Helens. is very heavily overloaded. Great alluvial fans of fragmental materials, mostly of a very fine character, are found in the North Fork valley at the base of the mountain. Their development here has resulted again in effectually damning the headwaters of North Fork and producing the beautiful and widely known Spirit Lake. This little lake, with waters icy cold and sparkling, lies like a crystal emerald at the northern base of Mt. St. Helens. Its surface elevation is 3,199 feet, and, unlike Merrill Lake, it has a surface stream outlet.

Lava Deposits on the Eastern and Southern Slopes

On the eastern and northeastern side of Mt. St. Helens the flowing tributary of Muddy River, approaches within three miles of the crest of the old volcano. The essential absence of volcanic fragmental materials and lavas on this side at elevations below

4,000 feet is conspicuous and interesting. On the southeastern and southern flanks of the mountain about the headwaters of Muddy River, Pine Creek, Swift Creek, all southward or southeastward-flowing tributaries of Lewis River, there is found the largest single expanse of volcanically modified physiography in the entire area. In this section pyroclastics occur only in relatively insignificant quantity. This whole area, comprising between 40 and 50 square miles, is a broad southward and southeastward-sloping lava flow. The lava in many places is hundreds, perhaps thousands, of feet thick. It extends from the base of the mountain to the waters of Lewis River. At this point its rapidly increasing viscosity, induced by contact with the then swollen river, caused it to pile up several hundred feet in thickness in the debouchures of the former creeks and branches. The more liquid flows behind were ponded, and the crests of the former ridges were left as the only abrupt physiographic features of the immediate vicinity—rock islands in a sea of rocks. These broad and probably more or less quiet, though destructive, lava extensions distributed themselves between Marble Mountain (4,100 feet) and Cinnamon Peak (3,940 feet), which elevations are remarkable only as the highest points of the country rock presenting the original accordance of summit levels.

Topography of the Region

A careful examination of the topography, both in the field and as reproduced on the Mt. St. Helens quadrangle, reveals a region broadly uplifted between 2,000 and 3,000 feet, with a somewhat poorly defined major axis about 20° east of north in the Mt. St. Helens vicinity. This axis will fall in line generally with Cinnamon Peak (3,940 feet); the crest of Mt. St. Helens and the lesser peaks to the immediate north; the Dome (5,703 feet); Mt. Margaret (5,847 feet); Mt. Whittier (5,818 feet); Goat Mountain (5,390 feet); Strawberry Mountain (5,732 feet); and Tumwater Mountain (5,249 feet)—the latter three of which form a portion of the southern watershed of Cowlitz River and its southern fork, Cispus River. Mt. St. Helens is located toward the southern extremity of this broad uplift, the first volcanic eruptions having broken out in the then headwaters of the South Fork of Toutle River.

TOPOGRAPHY OF MT. ST. HELENS AND VICINITY

Natural Phenomena of Interest to the Explorer

For the ardent explorer the Mt. St. Helens region offers many natural phenomena of interest besides the superb moun-

tain scenery at every hand. If he goes in by the Lewis River post road with the mail he will stop at the end of a full day's travel at Cougar, which is a log cabin post office and the end of the route. Here the great southern lava flows with their old fumaroles and small gas cones are within a mile's walk. A climb of five hundred feet from the river level brings one to the top of the flow, where large areas of submerged forests are seen to have stood, the rough scoriaceous lava having filled in about them *in situ*. Where the great trees once stood the traveler will see hundreds of vertical or semi-vertical manholes in the former lava flood, now cold and partly moss-covered. If he examines closely these chilled lavas he will note that their surfaces are pitted and grooved as casts of the charred timber about which the cooling lava set into solid rock.

About a mile up the lava flow, at an elevation of 1,351 feet, occurs the lower entrance to the largest of the several lava caves of the Mt. St. Helens district. It is reported that this cave, which is really an elongate abandoned laval channel, is over a mile in length. This report, though it may be true, is not here-with authenticated. The lava cave trail will lead the mountaineer to McBride Lake or Butte Camp, if he cares to follow it, from whence he may easily make the ascent of the main elevation of Mt. St. Helens in one day, returning to Butte Camp for the night. He may then return over the Kalama River trail, passing by Kalama Falls and Merrill Lake where, if he cares to tarry, unsurpassable trout fishing may be found.

A more extended trip, and one of very great interest, takes the traveler to Lange post office on the shore of Spirit Lake north of Mt. St. Helens. The Toutle River trail, which swings to the north below Butte Camp, crosses the South Toutle River canyon at an elevation of 2,886 feet and continues almost due north to North Toutle River, whence it turns east three miles to Lange and Spirit Lake. On leaving Lange the traveler may either retrace his steps to Cougar or go out with the mail down the valley of North Toutle River to Castle Rock and Cowlitz River.

Old Capitol,
Frankfort, Ky.

IV

PRELIMINARY NOTE ON THE OCCURRENCE OF VERTEBRATE FOOTPRINTS IN THE PENNSYLVANIAN OF OKLAHOMA*

During the summer of 1916, while mapping the structural geology of a portion of the Osage Nation, Oklahoma, the writer had the good fortune to discover a series of casts of vertebrate footprints in one of the sandstone members of the Middle or Lower Pennsylvanian. The location of the bed containing these fossil trails is in Township 27 North, Range 10 East, Section 31

CASTS OF FOOTPRINTS IN OKLAHOMA SANDSTONE

in Elm Creek about six miles northeast of Pawhuska. Stratigraphically the clay-sandstone member in which the casts of the animal tracks are preserved is calculated to be about 200 feet below the top of the Elgin sandstone which Adams, Girty, and White[1] regard as the Oklahoma equivalent of the Kanwaka shales of Kansas. As the Elgin sandstone is somewhat thicker in Oklahoma than in Kansas this would correlate the track-bearing horizon of the formation with the uppermost part of the LeRoy shales of Kansas.[2] This correlation fixes these beds as middle or lower Pennsylvanian, which is probably as close a determination as can be made until the Oklahoma Carbonif-

---

*American Journal of Science, Vol. XLIV, July, 1927.

[1]Upper Carboniferous Rocks of the Kansas Section, U. S. Geol. Survey, Bull. No. 211, p. 45, 1903.

[2]Idem., pp. 65-66.

erous and Permian in their relations to the Kansas equivalents are better understood.

Fossil footprints, or casts, from this undoubted marine horizon of the Oklahoma-Pennsylvanian series have never before been described, and because of their rarity such occurrences are to be regarded with interest. The slab on which the casts occur is about one foot thick. It is overturned from its original position above a soft gray clay which has been recently removed at this point by the waters of Elm Creek. Both the impressed clay and the casting sandstone are small and unimportant members of a long series of interbedded layers of sandstone and shale. Al-

OVERTURNED SANDSTONE SLAB WITH CAST FOOTPRINTS

though a diligent search was made, no exposure of the original upper surface of the clay could be found. Due to the nature of the clay deposit, it is not thought that it will ever be possible to collect anything of greater significance from this locality than these casts.

The specimen shows a double trail of casts across the slab. In the upper trail the movement was from left to right, and just below one may note the probable return or "back-tracking" of the same individual. Whether this creature was amphibian or reptilian there is no absolute proof, though many small factors point toward the former. Being adapted to a strandlike habitat it undoubtedly possessed aquatic tendencies,

which statement finds considerable support in the size and physical character of the foot impression. A five-toed animal, its feet were apparently almost as broad as long, and this, taken into consideration with the close proximity of the footprints, suggests: (1) a poor adaptation to land locomotion or crawling; (2) probably a more efficient adjustment to swimming or paddling, and (3) a compromising of these two in a bottom crawling. Detailed anatomical studies of these tracks are planned, and the results, with a series of measurements and outline diagrams, will be presented in a later paper.

One of the striking features of this slab of sandstone casts is the absence of the impressions of the feet of one side of the animal in both series of tracks. This peculiarity is generally to be accounted for in one of two ways. First, the animal may "back track" over one of the lines of fresh impressions with the result that the superimposed body weight flattens out and destroys the new undried tracks. In this case, however, the double track of the last movement should be left undisturbed. The specimen, however, does not show this double track. Second, an explanation for the single series of impressions is frequently found in the steeply dipping surface of muds on which the animal crawled along. Such a condition would of course give a series of good impressions on the lower side of the body, but on the upper side of the animal there would be very poor impressions or none at all. Tracks made under such conditions might be expected to show pronounced evidence of the fact in their increasing outward impression. A strong heel impression ought also to occur. Neither of these characteristics can be said to occur in these tracks, and as a result present speculations as to the reason for the absence of the complementary series of tracks have led to no definite conclusions. Only the very slightest and most occasional tail groovings could be detected, indicating very possibly the comparative physical insignificance of the caudal appendage.

The block herein described has been presented by the writer, at the suggestion of Drs. M. G. Mehl and R. L. Moodie, to the Department of Geology of the University of Oklahoma.

Yale University
New Haven, Conn.

V

EMORY RIVER OVERTHRUST OF EAST TENNESSEE*

During the autumn of 1919 while engaged in geological reconnaissance in the region adjacent to Crab Orchard, Cumberland County, Tennessee, a zone of considerable deformation was noted in Morgan County along the Emory River from Oakdale Junction northwestward to Nemo. Faulting and folding were so apparent even from the coach window of a passing train at a number of points within this region as to arouse many interesting structural speculations. The first impulse was to associate

EMORY RIVER FLOWING ALONG FAULT PLANE AT NEMO.

this deformation with a northeast extension of the Crab Orchard anticline and fault. A subsequent investigation of the topography of the Wartburg Sheet seemed to rule out these first surmises, and suggest other structural alignments of a more important character. A study of the areal geology as mapped on the Wartburg Folio[1] seemed in many ways to substantiate these larger implications, and yet at the same time to contradict them Only one minor fault, and that with a northeast-southwest strike, is referred by this work to the Wartburg Quadrangle.

Definite conclusions thus being impossible even in a general way, the writer again went into this field during the early part of April, 1923, with the idea of finding a solution to this vexed

*Pan-American Geologist, Vol. XXXIX, pp. 373-378, June, 1923.
[1]Wartburg Folio, U. S. G. S., Atlas, No. 40, by Arthur Keith, 1897.

problem. These investigations resulted in the discovery of a marked line of dislocation, which is termed the Emory River fault[2] and which is, in effect, throughout its principal extent, an overthrust from the southwest roughly paralleling the Emory River from Nemo to Deermont Station (see map,[3] page 75). It was traced from the waters of Bitter Creek, where it joined the north Oliver Springs fault, through to the region of the Clear Creek, a southeastward flowing tributary of the Obed River. The coal measures at all points north of the Emory River fault are dropped as compared to those southwest of the fault, thus producing in the Brushy Mountain region of Morgan, Anderson, Scott, and Campbell counties a thick, roughly wedge-shaped, rectangular, down-faulted block of Pottsville sediments.

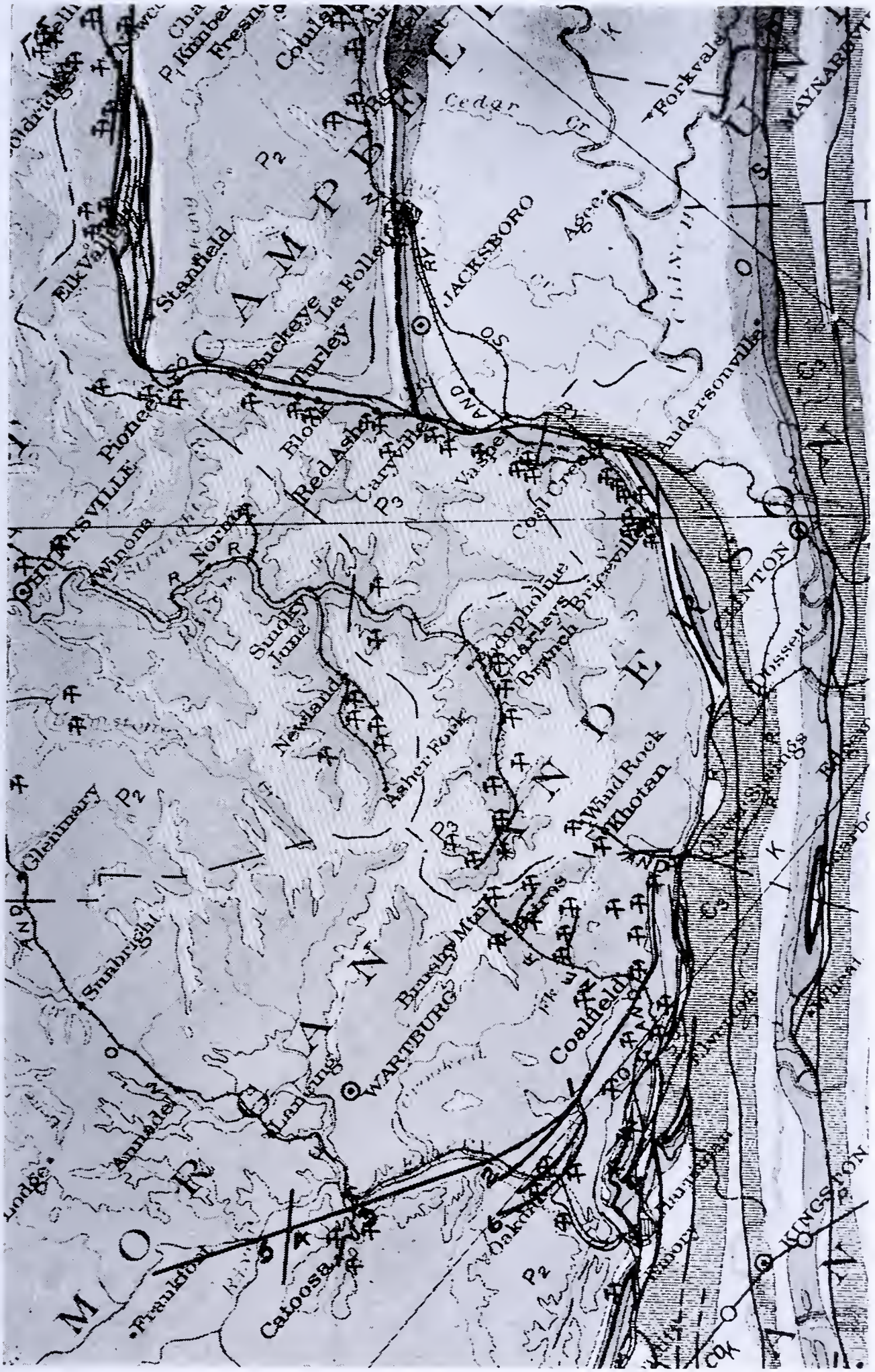
The Emory River fault is seen to best advantage in the vicinity of Nemo and Deermont, but it is plainly visible at many other points both to the southeast and to the northwest. On the head of Bitter Creek, where it takes off from the north Oliver Springs fault, dips to the southwest at a low angle are found three-quarters of a mile over the divide from Mud Lick Creek, on the Oakdale and Wartburg road. These increase into a small sharp fold in which crushing is evident. A fault of minor importance is noted in this fold. Passing to the northeastward, just beyond a sharp bend in the road, the strata may be observed inclined at angles varying from 15 to 25 degrees. Lower, on the waters of Whetstone Fork of Bitter Creek, the massive sandstones show dips ranging from 25° to 40° south 60° west. A fold of considerable figure may be seen in the hillside north of the fault. Sandstones are rendered quartzitic, and displacements ranging from 250 to 300 feet are figured based on the coals. The strike of the Emory River fault here is north 60° west.

Passing through the hills to the northwest deformational criteria are less pronounced, but at Deermont the fault is seen to excellent advantage. It is first observable one-quarter of a mile below Deermont Station where it is doubled with a fractured horst down-faulted. The displacement here is small, probably less than 100 feet. The strike at this point is north 55° west as

---

[2]Name here used for first time.

[3]This map is a reproduction of a portion of the geological map of Tennessee (Nelson, 1923, scale 1:500,000) on which the Emory River Fault, 1 to 5, has been indicated. The Hatfield Mountain Fault is at 4, Nemo at 3, Deermont at 2, and the Oakdale Fault extensions in the vicinity of 6. Lettering indicates true east and west.



GEOLOGY OF BRUSHY MOUNTAIN REGION OF EASTERN TENNESSEE

may be noted in the resistant sandstone ledges outcropping in the Emory River. Just above Deermont Station intense folding occurs on the northeast side of the fault (see photo, page 79) and here again the Lee sandstones, which are only slightly conglomeratic in this region, have been metamorphosed into quartzite, dark shales having been rendered subschistose, and thin, bituminous coals having been rendered subanthracite. The fold quickly dies out as one progresses to the northward along the railroad right of way, but throughout the distance from Deermont to Nemo dips of one and two degrees are observable on the north side of the Emory River. Throughout this distance the Emory River has adjusted its course to the strike of the fault.

At Nemo, the fault and the fold scissor and are a unit, the fault passing through to the south of the fold in this vicinity. The zone of extreme deformation is very apparent, and may be seen to advantage from the railroad bridge leading to Catoosa over the Emory River at the mouth of Island Creek. At this point, and for some little distance above, the Emory River flows along the strike of the fault in the fault-zone (plate xxix, figure A). Massive quartzitic sandstones above the railroad bridge show dips of 60° to the southwest and below the railroad bridge in the Emory River, where the fault goes into the White Horse Mountain, dips of from 60° to 80° are observable. The erosional surface of the southwest flank of White Horse Mountain is actually a bedding surface of the Lee sandstone dipping to the southwest. The mountain is thus one of actual elevation rather than erosion.

North of the county bridge crossing the Emory River at Nemo, the Emory River fault is plainly observable in the hillside as one goes up the road. At this point the sandstones and shales, within a restricted zone of about 400 feet, may be seen standing at an angle of from 80° to 90° with some considerable overturning indicated in the resistant sandstones (plate xxix, figure B). The displacement here is great, possibly 700 to 900 feet more. It is thought that softer sediments at the top of the Mississippian Series are not far below the drainage at this point. From just above the county wagon-bridge to the base of White Horse Mountain at Nemo, the Emory River flows directly in the fault itself, the semi-vertical quartzites giving rise to shoals and ripples.

Progressing up Rock Creek the fault is seen to pass into the northwest hillside. Massive sandstones of the Briceville shale cap the ridge and dip to the southwest at an angle of 20°.

On the eastern extension of Hatfield Mountain, at elevations of 1,500 feet, the massive Pottsville sandstones capping the ridge are again found dipping to the south 35° west at angles varying from 15° to 20°. The north face of the main ridge of Hatfield Mountain exhibits a pronounced anticlinal fold with a fault on the northwest side. The Emory River fault and fold crosses the Hatfield Mountain fault and fold at this point transversely. Prominent sandstones on the north face of the Hatfield Mountain anticline dip north 35° west, and south 35° east. These

DEFORMED POTTSVILLE SANDSTONES IN FAULT ZONE AT NEMO

sandstones are greatly fractured and fissured at the crest of the anticline, and take the form of a minor anticline on either side. In the region of the fault on the northwest side of the mountain, sandstones inclined to 80° occur.

At the mouth of Clear Creek in the Obed River cliffs, the Emory River fault and fold is again observable from the top of the gorge at a point just north of the mouth of Clear Creek. At this point the fold, which may be seen in the top of the massive cliff-forming sandstones, occurs definitely just south of the fault, which is here of normal figure. The upthrow side, however, is still on the southwest, the downthrow being on the northeast. The gorge of the Obed River at this point is from 300 to 350 feet deep, allowing an excellent section. Folding may also be seen

in strata in the point between Obed River and Clear Creek, the fault and fold extending on to the northwest along a strike of north 55° west. The ultimate extension of the Emory River fault to the northwest is unknown, but it is thought that it will not extend much farther than the great bend in Clear Creek, as it has the appearance of dying out in the Obed River.

Surficial rocks in the Emory River region of Tennessee consist of an alternating sequence of sandstones, shales and coals which have been designated as Pottsville in age, subdivided[4] into (*a*) the Lee formation (massive conglomeratic sandstones, shales and coals), (*b*) Briceville shales (dark gray, argillaceous shales, thin sandstones and thick coals), (*c*) Wartburg sandstone (sandstone, sandy and argillaceous shales, and coals), and (*d*) Scott shales (argillaceous and sandy shales, sandstones, and coals), a total thickness of about 2,100 feet. Of this not more than 550 feet are to be found at Nemo though sections ranging from 1,000 feet in Hatfield Mountain, two miles to the northwest, and 1,650 feet in Lone Mountain, five miles to the southeast, occur within the region at points slightly removed from the Emory River.

The resistant conglomeratic sandstones of the Lee division form the 350 foot gorge of the Obed River. Coupled with uplift they give rise to White Horse Mountain. These strong sandstones also outcrop as pronounced cliffs along the Emory River and its larger tributaries. Southwest of the Emory and lower portions of the Obed rivers the thick Lee sandstones are responsible for the development of the pronounced Cumberland plateau, the "Tableland"[5] of older geologists, into which the streams are incised. Northeast of the Emory River and fault quite a different type of topography is found. Due to the normal northeast dips of the strata and the down-faulting of the Brushy Mountain block east of the Emory River fault, the massive Lee sandstones so well shown in western Morgan, Cumberland, and Fentress counties are to be found generally below drainage. The result is a maturely dissected hill and valley country with an occasional mountain of erosion where the thick stratigraphic pile remains capped by a somewhat resistant sandstone. The drainage is of the dendritic pattern. The valleys are narrow

---

[4]Wartburg Folio. U. S. G. S., Atlas. No. 40, Keith. 1897.
[5]Geology of Tennessee, J. W. Safford, Nashville, 1869.

in the bottom and meandering, and the hill, flat-topped and irregular, finger out from the individual mountains. The region of the Emory River fault shows maximum elevations of about 2,500 feet and minimum elevations of about 850 feet, giving a normal physical relief of 600 to 700 feet.

A rapid examination of the region immediately southwest of the Emory River fault shows it to be conspicuously deformed. Normal and thrust faulting, intense folding, crushing and metamorphism occur more or less regularly distributed over a distance of two to three miles. Sharply faulted strata, accompanied by small faults with an occasional considerable overthrust from the

CRUSHED POTTSVILLE SANDSTONES NEAR EMORY RIVER VAULT AT DEERMONT

southwest, as may be noted about five-eighths of a mile below Deermont, and again at Hanging Rock, and at other points nearer to Oakdale, indicate to what extent direct movement has taken place in this region. On the lower waters of Island Creek from Catoosa to Nemo the same characteristic is to be observed, and again a short distance above Catoosa. Though no attempt was made to connect up or trace out these several lines of deformation, it is evident that they are all related and that the aggregate movement from the southwest toward the resistant and competent Brushy Mountain block, northeast of the Emory River fault, as revealed in the folding, crushing, shearing and overthrusting, has been considerable, perhaps as much as a mile or two in places. The transverse folding and faulting of the

Crab Orchard anticline, so prominently reflected in the Crab Orchard Mountain, evidently strengthened and intensified the driving movement to the northeast, and resulted in the extreme deformation which has taken place in the vicinity of Nemo and White Horse Mountain, both of which occupy a crestal position on the Crab Orchard structure.

In conclusion it is worth while to reflect on the geographic position of the Emory River fault, which may now be regarded as the cause of the rather peculiar pattern made by the various divisions of the Pottsville Series in the Nemo and Deermont region. The down-faulting of the Brushy Mountain block containing about 600 square miles, attains a new significance. It is seen as a strongly resistant tongue of coal measures and subadjacent strata extending out in great competency against the combined pressure from the southeast along the Walden Ridge fault, from the northeast along the Jacksboro fault,[6] and from the southwest along the Emory River fault. Down-faulting occurred on all three of these faces, and this unique block overridden by incompetent strata from all sides preserved itself intact with only the very slightest disturbance. It has recently been shown by C. K. Wentworth[7] that the Cumberland block, bounded on the north by the Pine Mountain fault, on the east by the Russell Fork fault, on the south by Hunter Valley fault, and on the west by Jacksboro fault, is one of the most "remarkable quadrilateral blocks" in the whole Appalachian region. Conspicuous as the Cumberland block may be for its symmetrical development, its eroded anticline and uneroded syncline, and its possible movement of from 6 to 10 miles to the northwest, the Brushy Mountain block adjoining it on the southwest, though smaller, assumes quite as conspicuous a position.

Old Capitol,
Frankfort, Ky.

---

[6]Briceville Folio, U. S. G. S., Atlas. No. 33. Keith, 1897.
[7]Journal Geology, Vol. XXIX, p. 351, 1921.

VI

THE HARPETH RIVER DOME*

The area involved in this report is situated 16 miles west of Nashville, Tenn., on the Harpeth River, a northwestward flowing tributary of the Cumberland River. The nearest railroad station is Kingston Springs, a town of about 500 population, on

TOPOGRAPHY OF THE HARPETH RIVER VALLEY

the Nashville, Chattanooga & St. Louis Railroad. The Harpeth River Dome, the principal subject of this discussion, is an elongated uplift located in the central part of this area. The apex of this dome is two miles from Kingston Springs, north 30 degrees east, and one mile in an air line to the nearest point on the Nashville, Chattanooga & St. Louis Railroad.

The field work upon which this report is based was executed during the last two weeks of August and the first week of September, 1923. Cheatham County is without a base map, and for this reason a somewhat longer period than might otherwise have been necessary was required to prepare an adequate base at a scale of 2,000 feet to the inch. This was done by plane table by S. M. Mayfield under the direction of the writer. The geology was executed in detail by the writer personally, and is accurate as far as vertical elevations are concerned to within a foot. The horizontal control was excellent for the structural map, and this portion of the work is regarded as very accurate.

---

*Oil and Gas Journal, p. 58, January 10, 1924.

Topography and Drainage

Geologically the region in which the Harpeth River Dome is located is a part of what is known as the western "Highland Rim" of Tennessee. It is the hill region surrounding the rolling Bluegrass of the Central or Nashville Basin. Geologically it is composed of the limestones, sandstones and shales of the Silurian, Devonian and Mississippian age which rest upon the Ordovician limestones of central Tennessee. The region is rugged. Maximum elevations of 770 feet are obtainable on the ridges of this area. A minimum elevation is found in the Harpeth River just west of the "Narrows." The maximum physical relief is therefore 310 feet, but throughout most of the area the difference between the ridges and the valley floor is from 200 to 250 feet.

The drainage is dendritic or tree-like in form, and the creek valley bottoms are narrow and meandering. The sides of the valley are steep, blanketed with a thin soil. Ledges of rock are frequently exposed. The uplands of the area exhibit the characteristics of an incompletely dissected plateau with the sculpturing by the streams approaching maturity. The region is located so as to center almost over the Harpeth River, the principal minor drainage being that of Hannah's Branch, Dog Creek, Scott Branch, Finch's Hollow, Mound Creek, Fish Trap Hollow, and a portion of the Harpeth River known as the "Narrows." This unique topographic feature was tunneled through on the Montgomery-Bell property for water power purposes years ago, and is now abandoned.

Stratigraphy

The rocks exposed at the surface in the vicinity of the Harpeth River Dome consist of limestones, shales and sandstones of Lower Mississippian, Devonian and Silurian age. The Mississippian rocks are the highest and constitute about 70 per cent of the area involved. They are known as the Fort Payne limestones; a cherty, siliceous and shaly limestone group. They have a maximum thickness in this section of about 300 feet Directly underlying this series occurs the Devonian formations, which consist in descending order of the Chattanooga Black Shale, 0-20 feet in thickness; the Hardin sandstones, 1 foot in thickness, and the Pegram limestones, 12 to 15 feet in thickness.

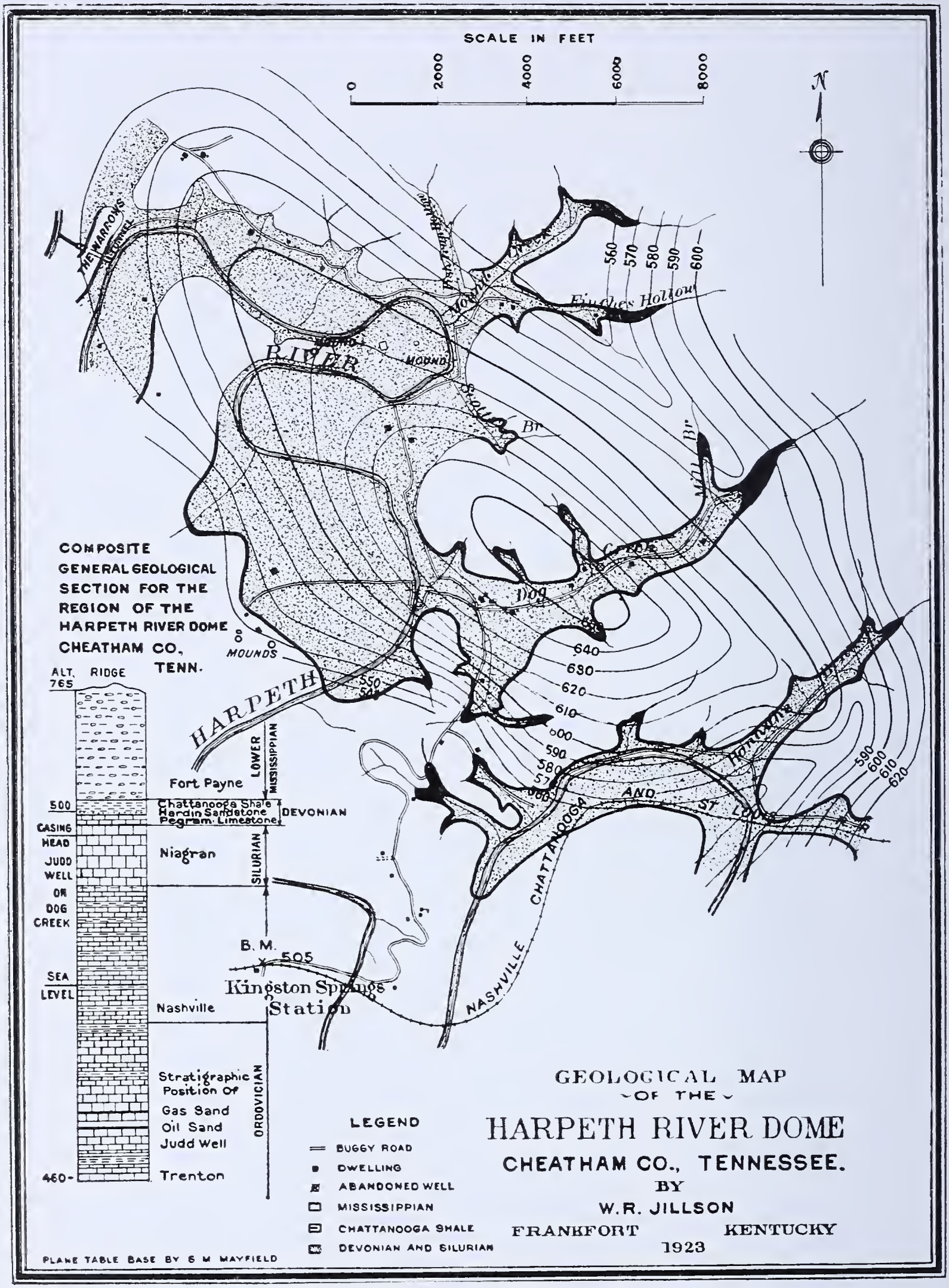
Underneath these Devonian sediments occur a group of Silurian limestones which may be grouped under the title "Niagaran." They are approximately 175 feet in thickness, exhibiting only their upper divisions in the regions closely adjoining the Harpeth River. Beneath this group of rocks, and unexposed anywhere within the region, occur the long series of limestones, shaly limestones, and impure calcareous shales of Ordovician

AREAL GEOLOGY OF CHEATHAM COUNTY
Dark area at A indicates Harpeth Dome.

age which have been subdivided into two groups: the Nashville (upper) and the Trenton (lower). These rocks have an unexplored thickness in this vicinity of upwards of 2,000 feet.

Structure

The Harpeth River Dome is an elliptical structure, the major axis of which extends in a northwest southeast direction. This axis, which is flexed into a flat crescent, is approximately north



THE HARPETH RIVER DOME

45 degrees west. The entire structure is about four miles in length, and slightly less than two miles in width. The dome closes with the highest contour at 650 feet, and the lowest contour of closure at 590 feet, thus exhibiting 60 feet of closure. The width of closure is about one and one-half miles, and the length of closure is about three and one-half miles.

The high point on the structure is located on Dog Creek, the structure giving an excellent section there with sharp dips to the northeast, and to the southwest. An excellent structural section is also to be observed along the Harpeth River in the bedded rocks within the first two miles above Mound Creek. The structure is not apparent but is existent as delineated for the entire region by elevations placed on the contact of the Chattanooga black shale and the Fort Payne formations. In the region surrounding the mouth of Mound Creek and to below the "Narrows" the Chattanooga black shale is absent, and here the section was built up to a normal thickness by adding the thickness of the black shale which would normally have been present.

Previous Development

The Harpeth River Dome has been drilled for oil and gas, one well having been located on Dog Creek. This well was drilled during the winter of 1887 and 1888, by a small group of independent operators who encountered gas at a depth of about 800 feet, and oil at a depth of about 840 feet. The well produced 1,240,000 feet of gas per day, and when the casing was pulled, 400 feet of high grade oil was found in the hole, according to the statement of S. S. Gorby, formerly State Geologist of Indiana. Mr. Gorby's report concerning the production of this well is borne out by that of residents in the countryside who remember the occurrence of oil and gas in this well. The company being poorly financed was unable to operate the well at a time of depression and slow market. Following the forced abandonment of the property, the well was plugged, and its location is now to be noted by the issuance of sulphur water from the Silurian limestones as a spring on the farm of J. H. Judd on the north side of Dog Creek.

This historical occurrence of oil and gas on the Harpeth River Dome is interesting since it indicates that either or both

of these fuels may be secured by intelligent prospecting on this structure. The occurrence of both oil and gas in the Judd well verifies their anticlinal position in this part of Highland Rim generally, and on this structure in particular. It is reasonable to assume that oil and gas may be expected at similar depths in other and probably better locations on this structure though the black Chattanooga shale (Devonian) is removed by erosion. Both oil and gas have been found in a number of old shallow wells in Dickson County, which adjoins Cheatham on the west and southwest.

Oil Sands

An inquiry into the subsurface stratigraphy of the Dog

TILTED DEVONIAN LIMESTONE ON FLANK OF DOME

Creek region reveals the fact that gas and oil secured at the respective depths of 800 and 840 feet below the surface on the J. H. Judd farm came undoubtedly from porous strata in the well known Trenton group (Ordovician age). No accurate log of the old Judd well was kept at the time of the drilling, and none is now available. These Trenton rocks, here found to be productive, are the source of much commercial oil and gas in northeastern Ohio, southern Kentucky and Tennessee. They are the rocks which are exposed in the central Bluegrass regions of Kentucky and Tennessee. The producing horizons here on Dog Creek may be similar to those which are now producing so largely in the Cumberland and Monroe County Fields of Kentucky and the adjoining Clay County Field of Tennessee in the Cumberland River Valley.

Conclusion

A summary consideration of the geology and known occurrence of oil and gas in this region leads to the conclusion that further prospecting for oil and gas on the Harpeth River Dome is worth while. Producing "sands" should be encountered at normally shallow depths of 850 to 950 feet, depending upon the location. Locations made in the bottoms high on structure will be shallow as compared to locations made up on the hills at lower points on the structure, which would of course require deeper drilling. Commercial production in "sands" below 1,000 feet in depth is not anticipated. Salt water horizons and conditions are not known. Drilling is recommended on the school house side of the structure on the lower waters of Dog Creek or as offset to the old Judd well. If production is secured at this point private pipe lines may be laid to the Nashville, Chattanooga and St. Louis Railroad at the first north bend above Kingston Springs. The entire length in an air line of such pipe lines to a loading track on the spur of the railroad would be approximately one mile.

Old Capitol,
Frankfort, Ky.

VII

EARLY MINERAL EXPLORATIONS IN THE MISSISSIPPI VALLEY (1540-1840)*

The story of the quest for mineral wealth in the great interior of North America is one which has its beginning in the dim obscurity of the ages. Indeed, the first evidences of mineral operations in the Mississippi River Valley and that part of the United States bordering the Great Lakes antedates the earliest continental explorations of the Spanish and French. Paleolithic miners then, possibly the remotely ancestral Indian, sought out the rich copper deposits of Isle Royale, a northern tip of the State of Michigan. Working there in great numbers, as evidenced by their countless artifacts and "diggings," and probably for a long time, they removed large amounts of native copper. Then in the course of time they disappeared as mysteriously as they came, and left no clew as to whom they actually may have been. When the first white men came into the region of the Lakes—Jesuit priests, traders and soldiers from France—these old copper excavations on Isle Royale, lapped by the waters of the great Lake Superior, were so ancient as to cause no interest whatsoever. In the cyclic lapse of the ages, through slow accumulation by erosion, the excavations had become partly filled, and in many instances great forest trees had come to take their place in them.

The Indians who occupied this territory prior to the coming of the first Jesuit missionaries knew nothing of these ancient miners. Though the good Catholic fathers crossed and re-crossed these parts, it seems never to have occurred to them, nor did it occur to later explorers, that this territory had ever been previously occupied. The size of the openings and the apparent thoroughness with which they were executed is indicative, however, that these early mining operations were carried out on a rather large scale and that extensive masses of native copper were extracted. These ancient excavations are not confined to one locality but are of general distribution throughout "Mineral Range" and Isle Royale. Occasionally entries and shafts to

*Transactions Illinois State Historical Society, pp. 41-57, 1924. Annual address presented before the Illinois State Historical Society, Springfield, Illinois, May 22, 1924.

the extent of sixty feet in depth have been found in which large masses of copper still remain, these being too large for the primitive miners to remove. Surrounding these masses of copper, sometimes many tons in weight, have been found countless stone hammers, pieces of burned wood, and other evidences of former mining labor. The procedure seems to have been to first heat the ore or metal with fires. Then by drenching with water and pounding with stone hammers it was disintegrated and separated into pieces small enough to be raised to the surface. The occurrence of these ancient diggings was not recognized until about 1847. or 1848, since which time they have served as a very valuable guide in detailed mineralogical explorations of this region.

The first mineral explorations in the Mississippi River Valley undertaken by Caucasians were those engineered by the Spanish in the early part of the sixteenth century. Reckless soldiers of fortune, they turned their eyes to this new land with a gnawing lust for the discovery of great riches. A leader in spirit and purse among these adventurers was Hernando De Soto, who, in his raiding expeditions through Central and South America prior to 1535, had acquired great wealth. Seeking new fields in his ruthless search for gold and silver, he planned an expedition into the heart of North America in 1538. Commissioned by Charles the Fifth of Spain as Governor of Cuba, he left Havana in the spring of 1539 and landed somewhere near Tampa, Florida, with a force of about 600 men. In midsummer he started his irregular and now somewhat indistinct course inland. He first proceeded northward as far as the Carolinas, then southward to the vicinity of Mobile, where he engaged in a rather extended battle with the Indians.

Successful in his military maneuvers, but failing to find any rich mines or treasure. he again turned to the northwest and reached the Mississippi River at the Chickasaw Bluffs in 1541. His explorations in search of precious metals, familiar to every school boy, were fruitless. Murder, arson, unnecessary brutality and repeated cruelty marked each step of his advance. As the exploration progressed, the tempting offers of the poverty-stricken, fish-eating natives seemed but to infuriate this heartless Spaniard and his followers. Nothing was found in the lower part

of the Mississippi Valley that could match the gold and silver treasure of Mexico, Yucatan, and Peru. The Journal (18, pp. 100-110*) of this first great expedition into the heart of America is pathetic in its recount of endless tragedy and disaster built upon the military plan of a continuous advance.

Three years after the landing in Florida, in the late spring or early summer of 1542, the indefatigable, cruel-hearted De Soto succumbed to disease as had so many of his faithful soldiers, and was secretly buried at night in the dark rolling waters of the Mississippi. So ended in fact the first mineral explorations in the valley of the Mississippi, for following the death of their respected commander, this ill-fated Spanish expedition broke up, and partly under the direction of Luis Moscoso, a lieutenant, descended the river in all speed to the Gulf of Mexico. At this point, desperately in need of relief, they turned westward, and the few who did not perish from accident, illness or starvation, finally joined their countrymen in Mexico.

The earliest explorations in the vicinity of Lake Superior were made by Charles Raymbault and Isaac Jogues, two Catholic priests who, with a party of Hurons, landed at Saulte Ste. Marie in the fall of 1641. They soon learned of the existence of a "big lake" exceeding the dimensions of any other of the Great Lakes, and were thus the first to take back to civilization the exact knowledge of Lake Superior. In 1660 Pierre Mesnard arrived at the "Saulte," and five years later Claud Allouez (20, p. 71) established a mission at La Point. In his diary Allouez makes reference to how the Indians worshiped Lake Superior as a divinity, and he states that he has observed them to carry pieces of copper, sometimes of considerable size, which they regard as domestic gods. In 1664 Dablon and Marquette prepared a map of Lake Superior and vicinity which was published in Paris three years later. A comparison of this early map with those of more recent date, shows the care with which these early Jesuit Fathers must have explored every part of the coast which this map represented. Overcome by accident, hardship and disease, Mesnard, Marquette and Dablon died in the unmarked wilderness. The occurrence of copper, however, at-

---

*Numbers in parentheses here and hereafter refer to item and page numbers as given in the Annotated Bibliography presented at the end of this paper.

tracted their attention and many references to it are to be found in their journals.

One of the earliest published records with respect to mineral explorations in this section is found in a small volume of less than 200 pages published in Paris by Pierre Boucher. He says, "In Lake Superior there is a great island 50 leagues in circuit in which there is a very beautiful mine of copper" (2, p. 8). On the map made by the Jesuit Fathers, Isle Royale is indicated as Minong (the good place). It was changed to Isle Royale following the conquest of Canada by the British.

The first mining operation of any size in this section was undertaken by Alexander Henry, who confined his explorations to the Ontonagon River near the spot where a large copper boulder had been found in the stream. Here he drove an entry into the hillside in 1772. The following year he sank a shaft into a small vein on the north shore. His operations were unsuccessful. Henry had originally pioneered his way to Mackinaw where he was engaged in traffic with the Indians. He was a man of some considerable education and had good social connections. After several years spent in this country he published an interesting narrative of his experiences and observations. In this account he describes the occurrence of a great erratic copper boulder on the margin of the Ontonagon River about 20 miles above its mouth, and suggests that its weight may be as much as 5 tons (1, p. 9).

In 1796 Captain Jonathan Carver published a report on three years' travel into the upper Michigan country in which he speaks of the Ontonagon River as a stream of considerable size that flows into the lake. He declares it to be remarkable for the amount of virgin copper which is found upon it, and states that the metal is also found elsewhere in the country. In vision he saw the future possibilities of the great copper mining industry in this northern part of Michigan, and suggested how metal might be carried in vessels to the Saulte around the rapids and barged to Niagara Falls where, followig additional portage, it might be placed in boats and shipped direct to Quebec and elsewhere (1, pp. 7-8).

Due to the good offices of Benjamin Franklin, who was in Paris during the American Revolution, this valuable mining ter-

ritory was saved for the United States. Doctor Franklin, one of the best informed men of his time, had heard of the occurrence of copper in the vicinity of the Great Lakes. Conceiving the region to possess a possible mineral value which would be developed at some future period, in subsequently arranging the treaty with the English he drew the boundary line so as to include the south shore of Lake Superior and all of Isle Royale within the limits of the new republic (1, pp. 5-6). In 1796 the Michigan Territory came into the possession of the American government, but the uncertainty of affairs which had existed, following the evacuation by the British troops coupled with the trouble with the Indians, made it impossible for Americans to go ahead immediately with mineral development of this section.

The land survey of Michigan was begun in 1819, and a little later, following some important Indian sessions, the lands were thrown open to sale. In this year Gen. Lewis Cass, the governor of the Territory, made an inspection under the direction of the War Department. He was accompanied by H. R. Schoolcraft in the capacity of geologist and engineer, the purpose being to determine as far as possible the truth of the reports of the mineral value of this country (37). In 1820, Schoolcraft's report on this section was issued and contains much interesting information. In 1842, the large boulder of native copper occurring on the Ontonagon River was removed by James Paull and was subsequently sent to Washington where it is now to be found on the grounds of the War Department (1, p. 10).

In 1841, Doctor Houghton, the first State Geologist of Michigan, prepared a preliminary report on the minerals of this region. This report contained the first bit of definite geological information concerning the occurrence of copper and the character of the rock deposits of Northern Michigan. A few years later, Doctor Houghton while engaged in the prosecution of a detailed survey of the entire upper Mississippi peninsula was drowned at the mouth of Eagle River. Many of the notes which he had prepared were lost. His previous announcements had, however, drawn public attention to the mining possibilities of this region. This unique Pre-Cambrian copper district now swarmed with speculators and prospectors, and the entire region was subjected to field investigations of one sort or another. The first general

mining operations were undertaken by means of about 1,000 grants or permits from the War Department at Washington. Altogether 960 locations were actually made, principally along the Keweenaw Peninsula. This portion of the country thus became the seat of the first modern mining work (1, p. 11).

In 1847 Professors Jackson and Whitney, U. S. Geologists, commenced a report (3) for the United States Government, the field investigations of which occupied a period of two years. A part of the work outlined by Jackson and Whitney was subsequently undertaken and executed by Messrs. Dickinson, McIntyre and Hill. Though they produced an excellent report on this important copper district it is singular that neither Jackson nor Whitney made any mention of the ancient mining excavations found throughout the district (2, p. 9).

The Lead Industry

Unlike copper, which was used by the aborigines for hunting and cooking purposes, there is no evidence to show that the early red men or their descendants, the Indians, made any use of lead previous to the appearance among them of the French explorers and missionaries. The French, like the Spanish, were continually in search for the precious and utilitarian metals, and appear at all times to have secured this kind of information from the Indians, as soon as possible after their entry into any particular section. Deposits of lead in the Fever River region, embracing parts of Wisconsin, Iowa and Illinois, in which Dubuque, Iowa, and Galena, Illinois, are now situated, were early made known to them by the savages. The introduction of fire-arms among the Northwestern Indians with the inducement to hunt for fur-bearing animals, made these rich Ordovician lead deposits of early importance both for the making of bullets and as a commodity for barter with the French.

It is thought probable that Wisconsin and Illinois Indians were first visited by Nicolet in 1634. Following their dismay and worshipful attendance upon him, after he had discharged his fire-arms, it is possible that they learned from him something of the use of gunpowder. Radisson and Groseilliers were in the Northwest in 1658-59, and it appears that they knew of lead mines in the vicinity of Dubuque. The great explorers Father

Marquette (1673) and La Hontan (1689) writing of their explorations, speak frequently of the mineral wealth of the Mississippi Valley, but it is not sure that they ever saw the lead deposits themselves, and there is some reason to believe that not seeing them, they thought them to be of gold, silver and copper.

Father Hennepin's exploration resulted in a map which was published in 1687, showing a lead mine in the neighborhood of Galena. Joutel, who was in this region about the same time, speaks of good lead mines in the upper part of the Mississippi. Nicholas Perrot, who commanded the French in the Northwest, visited the mines, it is said, about 1682, and conducted some smelting in this vicinity about 1690. Towards the close of the 17th century Le Seuer, an adventurer and trader. came over with D'Iberville's second expedition to Louisiana and with some miners ascended the Mississippi and undertook explorations on the Fever River in behalf of the French king. He worked the deserted Perrot mine and also some old diggings near Potsi. Wisconsin, but returned to France without advancing the industry perceptibly. In 1712 Louis XIV of France granted to Sieur Anthony Crozat a monopoly of mine privileges in Louisiana. including the entire Mississippi Valley. for fifteen years. It is not recorded. however. that he ever did anything with the lead deposits. though the Indian and English traders freely operated in this territory. Three years later. in 1715. Governor Cadillac of Louisiana, the founder of Detroit. conducted a search for reputed silver deposits. but brought back only lead ore.

Spasmodic frontier mining continued on through 1719 to 1722. The Crozat monopoly was resigned to John Laws' Company of the West without any considerable advantage to the district. In 1741, despite poor mining methods and very inefficient smelting. it is recorded that some 90 tons of pig metal were taken out by a score or more of miners working about four or five months in the year (4, p. 193). With the ceding by France to England in 1762 of the eastern half of the Mississippi Valley, and the secret yielding to Spain of the western half. complications again developed. Frenchmen remained the principal operators of the mines, and the lead became. next to furs. the most important product of this interior country. It was commonly bartered. the rate of exchange being a peck of corn

for a peck of ore. During the Revolutionary War the western forces frequently contended for the lead supply of the Fever River section.

The city of Dubuque, Iowa, takes its name from one of the most notable characters among the early miners of the latter part of the 18th century in this region. An Indian half breed, going by the name of Julien Dubuque, made valuable discoveries of lead in the bluffs adjoining the site of the present town, and to invite the favor of the Spanish then in possession of the territory he called them the "Spanish Mines." By the time Dubuque came in, the French and Indian miners had become quite experienced in lead mining though their operations were principally confined to the surface. Their methods, like that of the early operators of Michigan copper ore in the north, was to heat the ore by fire and then spall it off by dashing cold water against it. Mining tools prior to Dubuque's time were very simple, most of them being nothing more than buckhorn. Dubuque saw the inefficiency of their methods, and he may be accredited with the subsequent introduction of iron mining implements. The Indians loaded the ore down in "diggings" into deer-skin bags and then dragged or hoisted them along inclined surfaces to the open. Whenever a shaft was worked, the ore was removed in small leather bags by means of a rope made of deer-hide thongs.

Dubuque was well liked by the Indians and allowed a free range over their territories; consequently his operations covered a wide field. Following his death in 1810, lead mining was continued by the Indians, who, in 1819, made the discovery of the largest lead nugget found up to that time. The entire force of miners was necessary to raise this nugget to the surface. It has been estimated that up to this time a million pounds or more of lead had been extracted from these rich deposits. Following the Louisiana purchase in 1804, the United States assumed possession of the territory involving the Fever River mines, and shortly thereafter American pioneers and miners began to make their appearance. The newcomers, however, found little favor with the Indians, who preferred their old, easy-going friends, the French.

In 1811 George E. Jackson, a Missouri immigrant, built a lead furnace on an island in the Mississippi and floated his

product to St. Louis by flatboats. Indian depredations continued, however, and it was not until a treaty was finally signed with them at Prairie du Chien that the red men finally relinquished their hold on this important mining territory.

At this time Col. James Johnson, a Kentucky immigrant, came into this section. He mined the lead ore, and floated the product down to St. Louis by flatboat. Under the protection of a strong military force he returned in 1822, bringing with him a large party of negro slaves. He encamped where Galena now stands, and commenced a most extensive search for new lead deposits. His mines and smelting operations soon became the largest in the Fever River section.

Closely following Johnson's successful developments, there came in a large number of miners, prospectors and squatters from Missouri, Kentucky, Tennessee and Illinois. By 1825 the Fever River district was a boom camp, the population numbering up into the hundreds. West of the Mississippi River the heirs to the original Spanish claims held their mines to be private property, and the American prospectors and operators were warned to keep out. This disbarment of the territory west of the great river materially aided the development of the Fever River section.

Closely following the first investigations by Perrot in the Galena field, came the discovery of the occurrence of rich lead ores in the Meramec River region in what is now the State of Missouri. The find was made by a member of Le Sieur's party, which ascended the Mississippi River in the year 1700 (5, p. 267). In the journals of this expedition, reference was made to a mine reached by way of the Meramec, about 50 leagues west of the Mississippi River and west of Ste. Genevieve, whence it is said the Indians got their supply of lead. The outcrop, which occurs in rocks of Cambrian age, had evidently been known and used by the savages for some time. The Le Sieur expedition continued on up the Mississippi River, finding lead ores in operation near the southern boundary of Wisconsin.

Under the promoting genius of John Law, the Company of the West, or the Mississippi Company as it was known, started active operations in Missouri in 1717. The principal quest, however, was for precious metals, and so there is little wonder that

Sieur de Lochon, who was sent out by this great company in 1719, failed to accomplish much in his mining operations on the Meramec. Charlevoix has said (5, p. 268):

"He dug in a place that was showed him, took up a pretty large quantity of the minerals, a pound of which, that took up four days to melt, produced as they say two drachms of silver; but some persons suspect that he put in the silver." A few months later he tried for lead, "and from two or three thousand weight of the mineral he extracted fourteen pounds of very bad lead, which cost him 1,400 livres."

In the same year that de Lochon made his abortive attempt at mining in Missouri, Philip Francis Renault, son of an iron founder, was made Director-General of the mines of the Company of the West. He left France for Louisiana with 200 artisans and miners, among them being a man named La Motte, who is said to have been versed in mineralogy. The expedition absorbed at St. Domingo 500 slaves for the purpose of working the mines. It can thus be said that this early enterprise was responsible for the introduction of slaves into the west. Renault settled near Kaskaskia in 1720 and sent out exploring parties principally in the search of precious metals. One of these parties found two lead deposits, one of which subsequently became Mine La Motte in Madison County, and another which became Mine Renault, in Washington County. Renault instituted, with some considerable success, the smelting of the ores on a rather large scale. The product was sent to France via New Orleans. It is not improbable that a considerable industry would have been built up here in the heart of the Mississippi Valley, at this early date, had not the home enterprise, financed by Law, failed because of the collapse of the bank established by the company. Renault remained in the country ten years thereafter. Grants covering Mine La Motte were made to him as early as 1733 (?). But without money he could not develop these properties and in 1742 he abandoned his work and returned to his native country. Following this period of rather intensive exploration, conditions simulating the original again prevailed.

In 1763 Mine a Burton was discovered at what is now the town of Potosi in Washington County, the original find having been made by Francis Burton, a Frenchman, while engaged in

a hunting expedition. This mine soon produced as much as 1,800 tons of ore annually, and by very primitive mining methods (16, p. 2). During the latter part of the 18th century other lead districts in Missouri were gradually explored and to some extent developed. As finally defined they were found to number three and are located as follows: (1) the Southeastern district, south of St. Louis: (2) the Central District on the Osage and Missouri Rivers, and (3) the Southwestern District centering about Joplin. The Southeastern District, bordering the Mississippi River, was the first to be discovered and developed. The Central District and the Southwestern District were of later development in the order named.

In 1799 Moses Austin, a Virginia immigrant, introduced the first extensive semi-modern mining operation, sinking a shaft to the depth of 80 feet. He erected a reverberatory ash furnace and within three years had taken over the entire smelting business of the region. At the same time Austin erected the first tower for the manufacture of bullets, and a mill for the production of sheet lead. From these plants he supplied the arsenals at New Orleans and Havana.

During the period from 1880 to 1825 the development of lead deposits in Missouri increased greatly. This was brought about here as in the Fever River section to the north, by the growing security of titles and the recognition of the power of the United States based on the Louisiana Purchase. Under the Spanish rule four acres had been granted to all discoverers, while elsewhere on public lands all were allowed to work free from any tax.

Following the purchase of Louisiana, American regulations were introduced. Little attention was paid to them, however, and a chaotic condition soon arose with respect to titles to lead lands. Three-year leases were granted to discoverers by the governor of the territory, under congressional act. Reservations were made from reports of the land office surveyors out of St. Louis and the duty of leasing was attached to the office of the recorder of land titles. Rent charge was generally one-tenth of the ore raised. This system was very unsatisfactory, as few would take the trouble to take out a lease since there was no special agent to enforce it or protect the lessee. The maximum

length of the term was so short, too, that the mine could not well be opened and operated during the period.

As a result of the lack of a return from this poorly adapted system, local rules were gradually established by which a person was allowed to claim ground for 25 feet in every direction from the point in which his discovery was made, and others were allowed 12 feet square in which to sink pits over the adjacent ground. These claims they were allowed to hold until they abandoned the work. The price of lead at the mines during this early stage of the industry was four cents a pound; while the digging price was two cents. Costs of transportation to the towns along the Atlantic seaboard were prohibitive. The price of lead in 1819 in New Orleans was but five and one-half cents, while in remote Philadelphia it sold for only six cents a pound. It has been estimated that from 1740 to 1799 St. Genevieve County, Missouri (6, p. 531), produced approximately 1,000 tons of lead ore—the equivalent of 500 (6, p. 531)tons of metal—valued at $50,000. Madison County, from 1720 to 1799, is held to have produced 16 tons of lead ore (6, p. 525), valued at $800,000. Washington County mines produced 19,000 tons, equal to 9,500 tons of metal, on which a valuation of $950,000 has been placed (6, p. 535).

Other lead deposits occurring in the Mississippi Valley are found principally in Southeastern Illinois and Western Kentucky (7, p. 478) in faulted upper Mississippian (Chester) limestones. In Kentucky the ores have been mined intermittently by crude methods since the earliest settlers arrived.

In Illinois lead was discovered accidentally in sinking a well near Rosiclare in the fall of 1839 on the farm of James Anderson (8, p. 366), but the deposits were not extensively developed for many years thereafter. The deposits of this section occur in a fluorspar gangue as galena and are in a disseminated condition. They have generally been present in insufficient quantity to pay for their recovery as the principal metals and hence have been worked chiefly as a by-product of the fluorspar operations. During the early internal disorders, however, they have frequently served as a source of ammunition.

Coal Operations

As in the case of the discoveries of the metals in America,

coal makes its first appearance in historical records in the journal of a French Jesuit missionary, Father Hennepin, who, traversing the waters of the Middle Mississippi River, noted in 1679 the site of a "cole mine" on the Illinois River near the present city of Ottawa, Illinois (9, p. 24). Whether coal at this early date was actually mined and burned in this locality is an open question. The old journal does not say that it was, yet the use of the word "mine" is at least suggestive. The probability is, considering the train of subsequent events, that it was many years thereafter before it was actually used for fuel in this part of the country. The first commercial coal mining in the United States is recorded as occurring in the Richmond basin in Virginia 70 years after Father Hennepin's discovery of outcropping coal in Illinois.

In the Mississippi Valley and Great Lakes region is located the greater part of the important bituminous coal fields of the United States. These include: (1) that part of the Appalachian coal field situated on the Ohio, Kanawha, Big Sandy, Kentucky, Cumberland and Tennessee Rivers; (2) the northern interior coal field in the Michigan Peninsula; (3) the eastern interior coal field in the states of Illinois, Indiana and Kentucky, and (4) the western interior coal field in the states of Iowa, Missouri, Kansas, Nebraska, Oklahoma and Arkansas. An early knowledge of the burning qualities of coal by colonists residing on the Atlantic seaboard, coupled with the frequent occurrence of coal in the creeks and branches of the western territories, led to a widespread domestic development of the several coal fields of the Mississippi Valley at an early date. In all of these coal fields some local development of the coals followed directly upon the settlement of the region.

In Kentucky the first record of the occurrence of coal is found in the journal of Dr. Thomas Walker, who discovered coal in what is now Bell County, Kentucky, just inside of Cumberland Gap on April 13, 1750 (10, p. 28). Making a circuitous tour of exploration throughout eastern Kentucky he returned to his employers, the Loyal Land Company of Virginia, and gave in his report which showed the occurrence of coal at many points in what is now known to be the coal field of eastern Kentucky and southern West Virginia. In the following year

Christopher Gist coming into Kentucky from the north found many outcrops of coal on the waters of the Kentucky River, as his journal (12, p. 154) shows. He carried some samples back to his employers, the Ohio Land Company of Maryland, and thus became the first exporter of coal from the Ohio waters. Five years later, in 1755 (11, p. 25), coal was discovered in the Indian territory north of the Ohio River in what is now the State of Ohio. In the same year Lewis Evans prepared a map of the Ohio-Kentucky region, which was published, showing coal near what is now Greenup and Boyd counties, Kentucky.

It is very doubtful if the Indians in the Mississippi Valley made any extended use of coal for heating or cooking purposes though it is known through examination of their artifacts that they frequently used pieces of cannel coal for making beads and other ornaments. Some tribes may have known of its combustible nature, but the lack of general availability, coupled with the almost unsolvable problems of transportation and an inherent laziness in the Indian, operated against its use. In a section where wood and other carboniferous material was plentiful the mind of the savage could not easily associate fire with the black rock we now call coal. In the dry southwest, however, where combustive material has always been scarce, the Indian learned to use coal to some extent at least for firing his pottery. Lest we think that our white blood is so very far advanced over that of the red man, it is well to call to mind that the early copper and lead mining of the Mississippi Valley was carried on entirely without the use of coal, though the Illinois coal field closely adjoins the great lead deposits of Missouri, Wisconsin, Illinois and Iowa. Furthermore, the first iron smelting done in the Mississippi Valley as elsewhere in the eastern United States was made by the laborious charcoal process, while coal seams in many instances were found on properties contiguous to those in which iron ore occurred. In the early part of the nineteenth century coal was used to some extent in Pennsylvania, West Virginia, Kentucky, Tennessee, Ohio, and Indiana for smithing and domestic purposes, but the greater industrial use of coal comes at a much later date, and is a part of a much later period of American history.

Early Salt Manufacture

In the great valley of the Mississippi the occurrence of waters bearing salts suitable for table and medicinal purposes has been known from the earliest times. During the period of settlement the pioneers supplied themselves with table salt from springs which had long been known and used by the migratory Indians and the forest and plains animals. In all parts of this great expanse of territory the salt springs, or "licks," as they came to be known, were generously distributed. In Kentucky the best known were: Upper and Lower Blue Licks, Big Bone Lick, and those in Bullitt County on the Salt River, from which licks this stream derived its name. Other licks of lesser reputation were found in Lawrence County on the Big Sandy, on Middle Creek and Beaver Creek in Floyd County, at Flat Lick in Knox County, on the Cumberland River, and at Crab Orchard. Because of their economic importance, these salt licks were frequently the place of sharp and deadly encounter between the settlers and Indians. At Big Bone Lick, which is now in Boone County, Kentucky, as at many other salt springs, there have been found the remains of prehistoric animals. The occurrence of large amounts of mastodontic skeletal material at Big Bone is evidence of the fact that during the glacial period these huge mammals resorted to this spring for their supplies of salt. South of the glacial boundary, which is roughly the course of the Ohio River with a few overlaps into Kentucky, the salt springs and licks for the most part are very old, some of them undoubtedly dating back to the Cretaceous period or earlier.

During the period of settlement many pioneers devoted themselves entirely to the business of evaporating brines for salt at some of the larger springs. Such was the case in Southeastern Illinois in the Saline district. All early travelers through Southern Illinois and Indiana speak in their journals of the many important salt springs.

In many states, including Illinois and Michigan, reservations were set aside for the production of salt. In the case of Michigan an act of admission of this State into the Union in 1837 permitted the State authorities to select seventy-two sections of salt spring lands (13, p. 171). As the years passed, the supply of salt available at the springs became too small to serve the rapidly

growing interior, and shallow wells were drilled for brine or salt water at widely distributed points. In Kentucky the principal drillings were in Floyd, Clay, Wayne, Allen and Meade counties; while in West Virginia the valley of the Kanawha became a large producer. Kentucky-produced salt was used chiefly for local consumption, but that produced in the great valley of West Virginia and the Saline district of Illinois was barged down the Ohio and Mississippi to distant points.

Springs having a distinctly medicinal value were rather common and early patronized throughout the Mississippi Valley. In Illinois there were over a score (21, p. 62) and the same is true of the adjoining states of Indiana, Ohio, Missouri, Wisconsin, Michigan, Iowa, Kentucky, Tennessee, Arkansas and other points in the extreme north and south. Some of the springs had thermal qualities, and many are now known to possess mineral properties which make them analogous to the most celebrated springs and spas of Europe. A few such, as the Blue Licks of Kentucky, are known to be superior.

The Iron Industry

Though the savage aborigine was able to get along without the use of iron, the white settler of the Mississippi Valley, were the Spanish, French, British, or German, found it a prime necessity. During the period of early explorations in the 16th, 17th and 18th centuries, iron ores do not appear to have been considered. It is doubtful if the wide distribution of both high and low grade iron ores of the interior United States was at any time fairly appreciated. In the Wisconsin, Minnesota and Michigan areas, the Indian and Jesuit priests traversed and retraversed the greatest hematite ore bodies of North America without marvel. In western Pennsylvania, West Virginia, eastern Ohio and Kentucky the great deposits of iron carbonate ore were neither recognized nor sought out by the early explorers and settlers.

The great bodies of brown iron ore of eastern and western Tennessee, and western Kentucky, northern Arkansas and Missouri were also unknown. The large bodies of hematite occurring in eastern Missouri, southwest of St. Louis, as well as those of eastern Tennessee, were quite unsuspected and entirely unused until the latter part of the 18th century (22, map).

Although iron was first made in the United States on Falling Creek in Virginia in 1619, it was a long time thereafter before the industry established itself in the Mississippi Valley. While pig iron manufacture built itself up gradually along the Atlantic Coast, the colonial policy of Great Britain which prohibited the manufacture of iron implements from American ores operated to stifle the infant industry. For many years following the settlement of parts of the Ohio Valley, particularly those in the states of Kentucky, Tennessee and Ohio, all iron hardware had to be imported from the East. The dependency during these times of the pioneer West upon the skilled metal workmanship of the East, is shown by the fact that in the early settlement of the Ohio Valley the crank of the first saw mill, which was built in the year 1789, was carried by pack horses over the mountains to the Youghiogheny River and then shipped by water to its destination, 16 miles from Marietta. It weighed 180 pounds and was made in New Haven, Connecticut, for the New England Ohio Company (17, p. 26).

The first development of iron ore west of the Allegheny Mountains took place in eastern Kentucky, in Bath County, where the old Slate Creek furnace was erected at Owingsville in 1790 (14, p. 307). This furnace was built by Thomas Owings, a Maryland immigrant, who came from Baltimore for the express purpose of producing iron in eastern Kentucky. The ore used was an oolitic carbonate or siderite of Devonian age. A large forge was erected on the creek further down toward the Licking River and iron smelted at this furnace was here worked into stoves and other utensils. Cannon balls weighing four pounds were cast here, and were wagoned to the Licking River. Thence they were shipped by flatboat down the Ohio and Mississippi to New Orleans for the use of General Jackson in his engagements with the British.

About the same time (1790), Tennessee's pioneer iron works, a bloomery forge, was built at Embreeville (17, p. 24) in the eastern part of the State on the headwaters of the Nolichucky River in what is now Washington County. Shortly after the construction of the Slate Creek furnace a number of other furnaces were built in Eastern Kentucky. Some of these furnaces were located on the Kentucky River and its tributaries. One at

Clay City was erected about 1806 or 1808 by William Smith. Another built in this region became known as the Estill Furnace.

The successful establishment of the new furnaces in Eastern Kentucky was made possible by the high cost of transportation for manufactured iron products from the Atlantic seaboard to the interior. A furnace was established in Ohio in 1804. The ores used were carbonates, and the products made found a certain demand among the rapidly increasing settlements. A few years later, 1810, saw the establishment of a nailery in the Indiana Territory, which, it is said, in that year made 20,000 pounds of nails valued at $4,000.00. Many other states and territories successfully commenced the manufacture of iron during the early decades of the 19th century. In Missouri the extensive and valuable deposits of iron ore which had been early discovered were exploited soon after the first permanent settlers made their appearance. Iron was made in this State prior to its admission into the Union in 1821. In Wisconsin and Illinois the development was later, but in each of these states the mining and smelting of the ore for domestic purposes occurred prior to the year 1840.

In Western Kentucky the iron development was much later in getting started, the first furnace being erected about 1830 or 1837 in Cumberland River district. The Buckner Furnace near the junction of Pond River and Salt Creek in Muhlenberg County, a portion of the Western Kentucky coal field, was erected in 1837 (23, p. 178). After the year 1800 the iron industry saw rapid development in the middle of the valley, and from 1825 to 1860 it was a most attractive business where good ores were available. But during the height of the iron mining and smelting business in the Ohio Valley, ore discoveries were being made in the north about the Great Lakes, which discoveries were destined within a few short years to render the southern industry derelict at practically every point.

The discovery of iron in Michigan was made by William A. Burt, Deputy U. S. Surveyor, who, in the spring of 1844 while running special township lines, observed by means of the solar compass remarkable variations in the direction of the needle of his instrument, amounting to as much as 87 degrees from

the normal (15, pp. 9-14). Ascribing this phenomenon to the occurrence of iron ore he sought for it and found it on the ridges and on outcrop at several points. Specimens were collected by Burt and Doctor Houghton, the then State Geologist of Michigan, and were described by them in their official reports. The fact of the great magnetic variation, and the occurrence of the inferred large body of iron ore, received particular mention. William Ives, one of the party of surveyors, made a map of the region, on which he wrote the prophetic words, "iron hills" (15, p. 13).

The ores found were soft hematites and resulted in the opening up of the great iron ore industry of Michigan and the adjoining states of Wisconsin and Minnesota. These extensive iron ore beds are grouped into seven major districts or ranges, viz.: (a) the Vermilion, (b) Mesabi, and (c) Cuyuna ranges of Northern Minnesota; (d) the Penokee-Gogebic, and (e) Marquette, including the Republic and Swanzy; and (f) the northern Menominee (including Crystal Falls, Iron River, Metropolitan and Florence areas) of Northern Michigan and Wisconsin; and (g) the Baraboo and Iron Ridge ranges of Southern Wisconsin and the Spring Valley area of Northwestern Wisconsin.

The rocks in which these iron ores occur are very old, ranging from the Archean to the Cambrian. Two exceptions to this general statement are found in the Iron Ridge deposits, which are Clinton hematites, and the Spring Valley deposits, which are brown ores. The first shipment of ore from these wonderful Lake Superior deposits was made in 1850.

Miscellaneous Mineral Investigations

With the extinguishment of the Indian claims to lands in the central Mississippi Valley and the establishment of the sovereignty of the United States following the Louisiana Purchase in 1804, the development of the various natural resources, minerals and metals chiefly of a utilitarian value, proceeded in keeping with the settlement of the country. Fortunately at this time the needs of the new settlements were not many, and such minerals as had been found were sufficient to meet the necessities and provide some of the luxuries of frontier life. In the prosecution of lead mining operations associated deposits of zinc were found both in Missouri and Kentucky. The presence of ores

of this metal was recognized as early as 1810 by Bradbury at Mine a Burton, and it was later found to occur in many of the early mines in Washington County, Missouri. Schoolcraft, who made an early reconnaissance of this western region, predicted that the time would come when zinc would form the basis of a very important industry in the United States. The zinc industry in this country did not get under way, however, until 1838 when it was first manufactured at the Government arsenal in Washington. No furnaces for the reduction ores were constructed on the waters of the Mississippi until after the close of the Civil War (5, pp. 12-13, 274).

The discovery of petroleum and natural gas in the Mississippi River valley, like that of the soft metals and salt, is one which goes back to prehistoric times. When the first explorers and early settlers came into the great interior of this continent they soon became acquainted with numerous natural gas seepages which were called "burning springs." Not infrequently seepages of petroleum called "oil springs" were also found. This was particularly true of that portion of the Mississippi Valley which rests on the western flank of the Appalachian Mountains. Burning springs and oil seepages were of rather common occurrence on the waters of the Big Sandy, Kanawha, Allegheny, and the Monongahela. The commander of the French forces at Fort Duquesne, writing in 1750, describes how the Indians set fire to oil on a small creek as part of a religious ceremony (25, p. 186). Again, as in the case of zinc, though absolute evidence of large deposits of petroleum and natural gas was at every hand, the lack of a pressing economic need for these products operated to hold their development in check several generations.

In the course of boring wells for salt water, rock oil was first produced in the Mississippi Valley on the waters of the South Fork of the Cumberland River, in what is now McCreary County, Kentucky, in the year 1819 by Martin Beatty, a Virginian. Oil was found again in 1828 on the waters of the Cumberland River near Burkesville, Kentucky, by another salt well driller (24, pp. 3-5). Shortly following this period oil came to be of not infrequent occurrence in wells which were drilled for salt on the Great Kanawha River in what is now West Virginia. Strange

as it may seem, the discovery of an oil well of any description, good or bad, while drilling for salt at this early time was regarded as extremely fortunate. While the farmers used the petroleum for ridding their swine of vermin and for some few lubricating purposes, the most of it was allowed to waste away down the water courses.

The Burkesville, Kentucky, well drilled in 1828, an outstanding exception, was named the Great American Well, and from it quantities of oil were bottled and shipped throughout the country for medicinal use. About this same time oil seepages in Western Pennsylvania were used for this same purpose, the oil being recovered by the Indian method of digging a shallow hole or pocket in the rock at the oil spring. Blankets were then pressed against the seepages so as to take up the exuding petroleum. When the blankets were saturated they were wrung out by hand and the oil was caught in tubs. This product, put in bottles or barrels, was shipped down the Ohio or transported overland, labeled as "Seneca Oil," and was sold as a natural medicine compound.

In all this time it appears never to have occurred to anybody to drill a well purposefully to secure petroleum or natural gas. It must be remembered, however, that the common kerosene lamp had not yet been perfected, and that it was not known that American petroleum could be refined into a great series of fuel, lighting, and lubricating products until Professor Silliman of Yale College carried out his experimental tests of rock oil distillation in 1833. Modern petroleum refining goes back no farther than 1855 (26, p. 321).

The rapid growth of destructive distillation of certain carbonaceous shales and coals for paraffines, however, finally called attention to the possibilities of refining rock oil or petroleum. As the direct result of a fortuitous suggestion that rock oil might be secured by ordinary salt-well drilling methods, the Pennsylvanian Rock Oil Company was formed in New Haven, Connecticut. Colonel E. L. Drake was sent out by this concern to Titusville in Western Pennsylvania to undertake the drilling of an experimental well. As is now well known the work progressed successfully and Colonel Drake brought in at the great depth of 69½ feet the first drilled-for-oil well in America, on

August 29, 1859. The entire country was immediately electrified by the possibilities of the discovery. Modern oil and gas development followed, in the course of which tens of thousands of wells have been drilled, and hundreds of millions of barrels have been extracted, from the subsurface terranes of the Mississippi River valley.

There remains but one great mineral resource in the Mississippi valley, outside of the clays, cement and building stones, which are all of modern development. Fluorspar, the modern flux in the great steel and aluminum industries of America, was discovered in Southern Illinois and Western Kentucky at the time of the first settlements. Schoolcraft, in the course of his field reconnaissance, found flourite in this region and described it in 1819 (27, p. 160). This mineral was discovered in the Massac and Hardin County lead deposits in Southern Illinois in 1821. In the year 1835 the first Kentucky operation—the Columbia mine—was started by a company of which Andrew Jackson was the head. Fluorspar was later found in the Rosiclare mine in 1839, and was operated in 1842.

At first these spars were thought to be without value except in conjunction with the lead. At the present time the lead ore in this district is of very secondary importance. Fluorspar was not mined to any great extent in Kentucky until a good many years after its discovery, and it may be said, as in the case of petroleum and zinc, that the birth of this industry now so important to the industrial welfare of the nation was entirely dependent upon the perfection of methods of open hearth steel manufacture, and smelting bauxitic clays from which aluminum is refined. As in the case of zinc and petroleum, fluorspar explorations, such as they were, belong to the modern, rather than the early period of American history. They do not possess the glamour, the romance nor adventure that surrounded the quest for the great, soft, metallic deposits of the interior.

In summary, it is interesting to reflect that, while the lure of fabled deposits of silver, gold, and precious stones led the first European adventurers, traders and explorers over paths of blood throughout the Mississippi Valley, none were ever discovered. It is not likely that they will ever form commodities of importance in this part of the United States, except as by-

products of some other kind of mineral operation. The history of the many early failures to discover large deposits of precious metals and stones in this broad region is a sad repetition of discouragement, disaster and death. Later, during early colonial and Revolutionary War times, the growing discoveries of the basic utilitarian metals, lead, copper, and iron, in almost unbelievably large quantities, when coupled with the latent power resource of the great coal fields of this region, served to provide the economic foundation for the infant American Republic. At the present time these resources, spread out over a far flung system of connecting natural waterways, constitute, and will continue to constitute for many generations to come, the greatest guarantee to the industrial progress and political security of this nation.

ANNOTATED BIBLIOGRAPHY

(1) WRIGHT, CHARLES E.
Annual Report of the Commissioner of Mineral Statistics of the State of Michigan, for 1880. Lansing, Michigan, 1881.
A brief historical account of early mineral development in the Lake Superior Region.

(2) SWINEFORD, A. P.
Annual Report of the Commissioner of Mineral Statistics of the State of Michigan for 1884. Marquette, Michigan, 1884.
A brief historical statement of Isle Royale.

(3) FOSTER, J. W., and WHITNEY, J. D.
Report on the Geology and Topography of a Portion of Lake Superior Land District in the State of Michigan.
Part I—Copper Lands, Washington—1850. Printed for the House of Representatives.

(4) THWAITES, REUBEN GOLD
Early Lead Mining in Illinois and Wisconsin, pp. 191-196. Report of Proceedings of Ninth Annual Meeting of the American Historical Association. Chicago, Ill., July 11-13, 1893, in Miscellaneous Documents of the U. S. Senate, 2nd Session—53rd Congress, 1893-94. Vol. 4, No. 104. Washington, 1895.
A concise and systematic account of the first lead explorations and mining operations in this part of the Mississippi Valley.

(5) WINSLOW, ARTHUR
Lead and Zinc Deposits of Missouri, Vol. VI, Missouri Geological Survey. Jefferson City, Mo., 1894.
Historical sketch of Missouri lead deposits, pp. 11, 12, 13; of

Ky., pp. 151-155; Iowa, pp. 155-156; of Ill., pp. 149-151. Detail sketch of Missouri from earliest times to 1820, pp. 267-276.

(6) WINSLOW, ARTHUR
Lead and Zinc Deposits of Missouri, Vol. VII, Missouri Geological Survey. Jefferson City, Mo., 1894.
Statement of tonnage exported from St. Francois Co., from 1740-1820 and later on, p. 531.

(7) NORWOOD, CHARLES J.
Report of a Reconnaissance in the Lead Region of Livingston, Crittenden and Caldwell Counties, etc. Kentucky Geological Survey, Series II, Vol. I, Part VII. Frankfort, Ky., 1876.
Historical references, p. 478.

(8) NORWOOD, DR. J. G.
Report on Rosiclare Lead Mines in Geology of Illinois, Vol. 1, Illinois Geological Survey. Chicago, 1866.
Historical statement, pp. 366-375, relative to Southern Ill. and Ky.

(9) PARKER, EDWARD W.
Coal in the Mineral Resources of the United States for 1909, Part II, U. S. Geological Survey. Washington, D. C., 1911.
Contains some historical data on coal, p. 24.

(10) JILLSON, WILLARD ROUSE
The Coal Industry in Kentucky, State Journal Co. Frankfort, Ky., 1922.
A brief review of the discovery and development of coal in Kentucky in 1750.

(11) GEOLOGICAL SURVEY, U. S.
Coal in the Mineral Resources of the United States for the Year 1911.
Historical references, p. 25.

(12) JOHNSTON, J. STODDARD
First Explorations of Kentucky, The Filson Club, Publications No. 13. Louisville, Ky., 1898.
Gist's Journal containing many coal references, p. 154.

(13) GARRIGUES, S. S.
Report of the Salt Manufacture of Michigan. Vol. III, Appendix B, Michigan Geological Survey. Julius Bien, New York *City. 1876.*
Historical references, pp. 171-172.

(14) MILLER, ARTHUR M.
Geology of Kentucky, Ky. Geological Survey, Series V, 1919.
Reference to early iron mining and smelting in Kentucky, p. 307.

(15) BROOKS, T. B.
Iron Bearing Rocks in the Upper Peninsula (1869-1873), Geological Survey of Michigan, Vol. I. New York City, 1873.

Historical references to copper and iron ore discovery in Michigan, pp. 9-14.

(16) BUCKLEY, ERNEST ROBERTSON
Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Missouri. Missouri Bureau of Geology and Mines, Vol. IX, Part 1. Jefferson City, Mo. 1908.
A brief history of mining and production. pp. 2 and 3.

(17) SWANK, JAMES M.
The American Iron Industry from Its Beginning in 1619 to 1886, in Mineral Resources of the United States for the Year 1886, United States Geological Survey. 1887.
An excellent review of iron development in America, p. 23.

(18) FRENCH, B. F.
Louisiana Historical Collections, Part II. 1850.
Diary describing the De Soto expedition, pp. 107-108.

(19) MONETTE, JOHN W., M. D.
History of the Discovery and Settlement of the Valley of the Mississippi—Spain, France and Great Britain and the subsequent occupation, etc., until year 1846, Vol. I. Harper & Bros., 82 Clift St., N. Y., 1848.

(20) SHEA, JOHN GILMARY
Discovery and Exploration of the Mississippi Valley, etc., Second Edition. Joseph McDonough, Albany, 1903.
The narrative of a voyage made to the Illinois by Father Claude Allorez, p. 71.

(21) BARTOW, EDWARD, et al.
The Mineral Content of Illinois Waters, Illinois State Geological Survey, Bull. 10. Urbana, Ill., 1909.
General discussion of Illinois waters. Historical statement on medicinal springs, p. 62.

(22) HARDER, E. C.
Iron Ores, Pig Iron and Steel in Mineral Resources of the United States, year of 1908, U. S. Geological Survey. Washington, D. C., 1909.
Contains much informative data, and excellent ore map of the U. S. is attached, p. 61.

(23) ROTHERT, OTTO A.
A History of Muhlenberg County (Ky.). John P. Morton & Co., Louisville, Ky., 1913.
Many historical references to iron and lead development in Kentucky.

(24) JILLSON, W. R.
Oil and Gas Resources of Kentucky. Department of Geology and Forestry of Kentucky, Series V, Vol. 1. 1919. Second edition, 1920, revised.

Historical account of the first oil well in Mississippi Valley, p. 3.

(25) STOWELL, S. H.
Petroleum, in the Mineral Resources of the United States, for 1882-83, U. S. Geological Survey. Washington, D. C., 1883.
Historical review of petroleum development in America, pp. 186-187.

(26) ENCYCLOPAEDIA BRITANNICA (11th Edition), Vol. XXI. New York City, 1911. History of Petroleum, pp. 316-323.

(27) JILLSON, WILLARD ROUSE
Production of Fluorspar in Western Kentucky, Vol. II, Kentucky Geological Survey, Series VI. Frankfort, 1921.
Contains some early historical references.

(28) FOHS, F. JULIUS
Fluorspar Deposits of Kentucky, Kentucky Geological Survey, Series III, Bull. 9. Frankfort, 1907.
Some historical reference to fluorspar development in Kentucky.

(29) FLUORSPAR, LEAD and ZINC, Chapter VII, Bull. 41 (Geology of Hardin County, Ill.), State Geological Survey of Illinois. Urbana, Ill., 1920.
Some historical reference to fluorspar, p. 247.

(30) STRONG, MOSES
Lead and Zinc Ores (of Wisconsin) in Geology of Wisconsin, Vol. 1, Wisconsin Geological Survey, Madison, 1883.
Historical reference to lead development, pp. 637-639.

(31) IRVING, R. P.
Iron Ores (of Wisconsin) in Geology of Wisconsin, Vol. I, Wisconsin Geological Survey. Madison, 1883.
Historical references to iron development, p. 613.

(32) ASHE, THOMAS
Travels in America performed in the year 1806.
Various references to the occurrence and mining of lead, salt, copper, etc.

(33) WORTHEN, A. H.
Devonian and Silurian Systems in the Geology of Illinois, Vol. 1. Illinois Geological Survey, Chicago, 1866.
Historical reference, p. 141, to early French discoveries of lead in the Trenton group.

(34) COX, G. H.
Lead and Zinc Deposits of Northwestern Illinois. Bull. 21, Illinois Geological Survey, Urbana, Ill., 1914.
Short historical statement of lead and zinc mining and smelting in Illinois.

(35) WHITNEY, J. D.
Geology of the Lead Region in Geology of Illinois, Vol. I, Illinois Geological Survey. Chicago, 1866.

Historical reference and statement of volume of lead exported, pp. 156-157.

(36) SCHOOLCRAFT, HENRY R.

Travels in the central portions of the Mississippi Valley, etc., in the year 1821. Collins and Hannay. New York City, 1825.

Old Capitol,
Frankfort, Ky.

VIII

A NEW TENNESSEE OIL POOL*

The bringing in, on August 18, 1923, of the Eugene Marcom Well No. 1, at Willow Grove, in Clay County, Tennessee, by A. A. Alexander, *et al.*, has served to call attention to the unusual opportunities afforded the oil-and-gas producer in this shallow section of the southern Appalachian region. The productive horizon, which is regarded as the second Sunnybrook "sand," is 10 feet in thickness. Drill-cuttings indicate it to be a blue-gray, porous limestone, overlain by a thin, compact, impervious, black, calcareous shale. Tests in dilute hydrochloric acid failed

MARCOM No. 1, WILLOW GROVE, TENNESSEE

to show any considerable amount of insoluble siliceous materials in these cuttings. The "sand" was encountered at 412 feet, and the well was finished at 422 feet. During the first hour or two following the drilling in, the well flowed freely under heavy gas pressure uncontrolled; and it is estimated that about 500 barrels of oil were lost in the waters of Irons Creek, a northwestward flowing tributary of Obeys River.

After flow line connections to a 250-barrel gas-tight tank were made, the oil was conserved and the tank was filled within four hours. The well was then closed in. At the time the writer was engaged in making the reconnaissance of this field upon which this paper is based, August 24 to August 28, 1923, the Marcom No. 1 was driving petroleum under considerable gas-head along weathered bedding planes in the Upper Ordovician limestones to points 1,000 feet distant, where it emerged along the

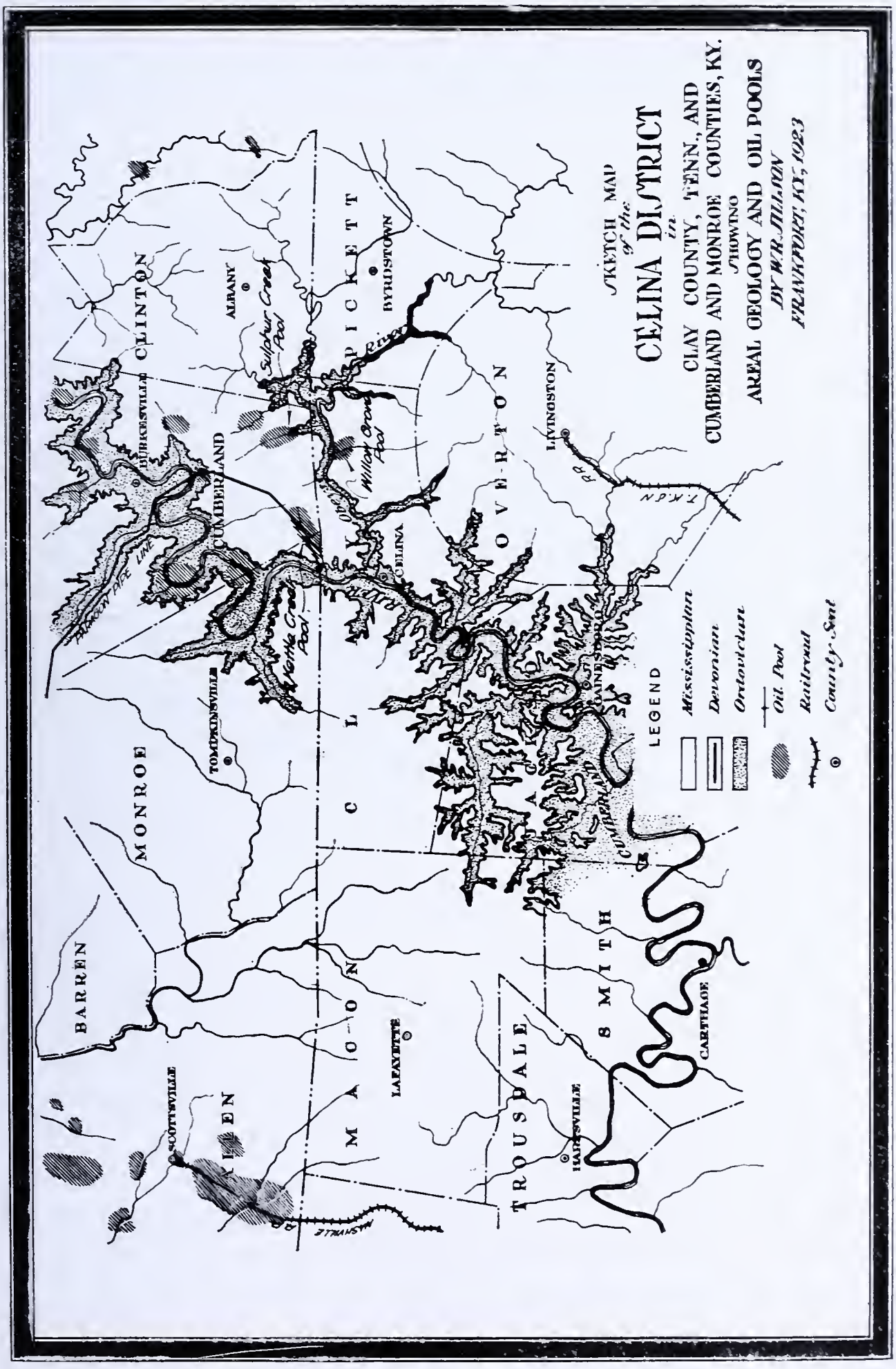
*Pan-American Geologist, Vol. XL, pp. 197-202, October, 1923.

adjacent waters of Irons Creek much like a fresh natural seepage and formed a bright "rainbow" on the flowing water. This discovery well is conservatively estimated at between 1,500 and 2,000 barrels of flush production. In some respects this well is much like the Budd Kerr No. 3, in the Kettle Creek (Kentucky) pool, which, after closing in when flowing at least 2,000 barrels per day under a strong gas-head, continued to produce into a capped creek gravel with the result that an offset well drilled to a depth of only 20 feet at a point four feet from the casing head of Kerr No. 3 is now producing between 500 and 1,000 barrels per day when tankage is available. This freak well is undoubtedly the largest shallow well ever drilled in Kentucky.

CHATTANOOGA SHALE ON LIMESTONE OF RICHMOND AGE ALONG SULPHUR CREEK

Willow Grove, Tennessee, is located just south of Obeys River on the lower waters of Irons Creek, in Clay County. It is 15 miles in air-line northwest of Livingston, in Overton County, Tennessee, and 17 miles southwest of Burkesville, in Cumberland County, Kentucky. The town, which is little larger than a county crossroads, is located on an Ordovician re-entrant which follows Obeys River into a northeast extension of the Eastern highland rim of Tennessee. Creek bottom elevations at Willow Grove are between 580 and 600 feet, a U. S. G. S. benchmark of 579 feet being located where the town's "Main Street" crosses Irons Creek. Hilltop elevations in this section are between 900 and 1000 feet, the general relief being about 400 feet. The valleys are fairly broad, covered with limestone and alluvial soil. The hills are timbered, and knob-like in appearance.

The stratigraphic section at Willow Grove includes representatives of the Mississippian, Devonian, and Ordovician sediments.



GEOLOGY OF THE CELINA DISTRICT

Silurian strata are not present. Above drainage, as shown in Pilot Knob (1,398 feet above sea-level), the Mississippian series is represented by the Cypress sandstone, Gasper limestone, Ste. Genevieve limestones and St. Louis limestone. The underlying dissected plateau is made up principally of the Warsaw, Fort Payne, and New Providence formations. The Mississippian formations show a total thickness of about 950 feet. The Devonian section is represented only by the Chattanooga black shale (30 feet), which, however, may have a Mississippian component in its upper portion.

The Ordovician beds are at drainage-level in the adjoining Obeys River, and for a short distance up Irons Creek are represented by limestones and shaly limestones which are of Richmond (Cincinnatian) and Maysville (Cincinnatian) equivalency. Their total thickness is perhaps 250 or 280 feet. Beneath, and not outcropping at the surface, are a succession of limestones and shaly limestones of Trenton (Mohawkian) horizon, represented by the Cannon limestones (300 feet) and the Hermitage shales (50 feet). The "Pencil Cave" (Bentonite bed) of drillers is here found delimiting the Trenton. This distinguishing horizon is in turn underlain by the Lowville (Mohawkian) limestones (400 feet), and the Stones River (Chazyan) limestones (400 feet), in descending order. The figures here given for the several divisions of the Ordovician section are, of course, estimates of thickness. A total of 630 feet is shown above the "Pencil Cave," and 800 feet below it, or 1,430 feet for the entire sequence.

The occurrence of oil at Willow Grove is distinctly anticlinal. The structure is an elongated dome of low, though pronounced, figure, the major axis of which is south 60 degrees east. Dips to the southeast of two to two and one-half degrees are obtainable on competent upper Ordovician limestone beds. A maximum observable height of 35 feet is recorded for this structure. The structure itself is five-eighths of a mile in width, and is at least one and one-fourth miles in length, possibly longer. Production was secured in a porous, bluegray limestone, at a depth of 412 feet, which is regarded in this section as the second, or lower, Sunnybrook "sand," and is in the Trenton section. Sixteen gas blow-outs were encountered in this well below 136 feet, in-

cluding the oil-producing horizon. All of these blow-outs removed the cuttings and the water from the well. No accurate formation-log of the well was kept. The stratigraphic position of its casing head, however, is about 20 feet below the base of the Chattanooga black shale. The blow-outs occurred at the following recorded depths in feet: 136, 153, 172, 188, 198, 216, 224, 226, 250, 268, 285, 303, 340, 355, 395, 412, and 422. A small amount of salt water was encountered at 260 feet, and a large flow of salt water at 365 feet. Casing 6¼ inches was set at 160 feet, 7 inches. At 392 feet, 6 inches, a soft porous limestone was encountered, and just above the top of the pay "sand" (412 feet) a gray-black calcareous shale, which evidently was the cap-rock of the productive horizon, was pierced.

KERR No. 1, DISCOVERY WELL, KETTLE CREEK, KENTUCKY

In the Kettle Creek (Kentucky) pool four miles to the northwest the following "sands" with depths, are now producing oil: (1) Shallow stray "sand," 168 feet; (2) First Sunnybrook "sand," 212-220 feet; (3) Anderson "sand," 295 feet; (4) Second Sunnybrook "sand," 392-450 feet. The last three of these "sands" are Trenton beds. Two additional deeper "sands" are now producing in Cumberland and Clinton counties, Kentucky, which lie immediately north of Clay county, Tennessee. Both of these deep sands are to be regarded as productive possibilities at Willow Grove and throughout this region generally. The first of these deep sands occurs at 1,050 feet below the Chattanooga black shale, and is probably in the Lowville strata; the second occurs at 1,300 feet to 1,350 feet below the Chattanooga black shale, and is the subject of stratigraphic dispute. Its depth would seem to indicate that it is a Stones

River bed. If in reality, however, this second deep "sand" is lower, due to a shortened section, it would necessarily occupy a position in the upper Canadian dolomitic limestones, which, like the sediments immediately above and below, are in this part of Tennessee only known by inference from somewhat distant localities of outcrop.

The drilling in of this large oil-well at a depth less than 450 feet at Willow Grove affords peculiar interest to the oil producers and others interested in the shallow fields of Kentucky and Tennessee. Like all of the Trenton oil of southern Kentucky, this crude product is light. A fresh sample collected by the writer gives a gravity of 39.7 degrees Baume. The region in which the Marcom well occurs is similar topographically and stratigraphically to that which has been largely productive at shallow depths just to the north in Monroe and Cumberland counties, Kentucky. Here in Clay County, as in Kettle Creek, and Sulphur Creek, large amounts of salt, sulphur, and fresh water may be expected in the Sunnybrook (Trenton) sands. Casings should be set at 160 to 200 feet.

The Willow Grove region lies near the saddle between the Lexington and Nashville (Rutherford) domes just east of the major axis of the Cincinnati Arch. It has been subjected to compression evidently at various intervals during post-Paleozoic times. The structures are plainly reflected in the Mississippian sediments, though most easily defined on the level between the Chattanooga shale and the underlying Ordovician limestones. The region as a whole contains a great many small folds, for which the one at Willow Grove may be taken as a type. No particular paralleling of major axes has been noticed. The Kerr anticline on Kettle Creek trends east and west while the structures at Willow Grove are turned to the southeast. The relatively small size of the structures in this vicinity indicates a succession of small, highly productive shallow pools for this part of Clay County.

Wells ranging from 10 to 1,000 barrels flush production may be drilled within the next year or two. Acre-foot production in barrels cannot as yet be figured due to lack of oil runs, but water is at all times to be feared. In case of the large flush producers, salt water encroachment is certain but may not be

protracted for many wells. Longer life is anticipated for the smaller producers. Large wells in this field will undoubtedly produce 5,000 to 15,000 barrels before going on the pump. Settled production will range from 20 barrels downward covering a period of 5 to 7 years. Drilling close to the productive "sands" should be done during daylight only, to avoid fire risk, as many of the wells drill in with a considerable gas-head. Flow line to gas-tight tankage, as well as casing head-gate valves, or

NORTHEAST FLANK, WILLOW GROVE ANTICLINE

"oil savers," should be used to conserve the flush production. Tens of thousands of barrels of petroleum have within the last year or two been allowed to waste themselves down the creeks and branches of this most promising oil-producing region of Kentucky and Tennessee.

Old Capitol,
Frankfort, Ky.

IX

SHADING OF CONTOURED TOPOGRAPHIC MAPS*

A significant advance in the fine art of accurately depicting earth sculpture on paper is recorded for the year 1921 by the Monument Springs (Texas) topographic sheet. This map was produced by the topographic branch of the U. S. Geological Survey, in Washington, D. C. and is a decided innovation in American cartography. Strikingly different in appearance it is similar nevertheless to all other standard "fifteen-minute topographic quadrangles." The map's real distinction lies in a unique and successful combination of ordinary topographic contouring with detailed brown shading which has been executed by Mr. W. R. Berry. It presents at once the very pleasing appearance of actual physical relief, substantiated of course by detailed, surveyed and contoured topography.

The Monument Springs sheet is scaled 1:62,500, with a contour interval of 50 feet. The minimum elevations are slightly less than 3,500 feet above sea-level, and are found adjoining the southeastern border on the waters of Maravillas Creek, which flows southeastward into the Rio Grande. The highest point on the map, 6,151 feet, is found in the northwestern part of the area along the crest of the Del Norte Mountains, thus giving a maximum relief of 2,651 feet, which, however, is so dissipated by the distance between these two widely separated points as to be imperceptible in its entirety.

This new quadrangle depicts the topography of an area in Brewster County, southwestern Texas, which, from a physiographic standpoint, is a typically Trans-Pecos country. Here is found an assemblage of topographic units, mountains, plains, and basins that defy collective description. Something of each of the dominant regional physiographic types seems present, the Rockies on the north, and the Mexican plateau on the south. The great variety of slopes and drainage patterns suggests, however, a more or less continuous and eventful geological history. The detailed geology of this region when executed will undoubtedly account for much that can only be suggested now.

Physiographically the area exhibits a broad, high plain, or

---

*Pan-American Geologist, Vol. XLVII, pp. 11-14, February, 1927.

PORTION OF MONUMENT SPRINGS SHEET
Reduction about one-half.

platform, known to be composed of late Paleozoic clastics and dark-colored limestones. This plateau is of low relief, varying from 3,600 to 4,200 feet. Rising above this level on the west, the rugged Del Norte Mountains, composed of Early Cretacian sediments, presents a sharp eastward facing scarp which is 1,200 to 1,500 feet high. To the west these elevations drop away on the intricately dissected upper waters of Maravillas Creek, which has entrenched itself in a canyon 1,000 feet deep across the crest of this range, and is therefore clearly antecedent in character. The Del Norte Mountains have Texan extensions to the north: and to the south into the Sierras Santiago, Bouquillas, and del Carmen, which are deeply trenched towards the Rio Grande. The physical aspect of the Del Norte Mountains suggests extensive faulting in the eastern middle portion of the area.

South and southwest of the town of Marathon a series of eight or more rather low "hog-backs" occur. These hills 400-700 feet high, involve the Monument Springs area itself, and are thought to consist chiefly of Late Cambrian sandstones and shales of a dark hue, known locally as the Brewster formation. These distinctive topographic features strike northeast and southwest and are the recently uncovered remnants of a much older unit uplift, significant in their proportions and widely differing in cause. Their figure is very suggestive of regional folding due to strongly compressive forces operating between the northwest and southeast. These hills drop to the southwest beneath the general platform of the area as they approach the vicinity of the rugged Santiago Mountains.

Reviewed in its entirety this new map of the Monument Springs area gives every appearance of being a happy combination of excellent modern topography coupled with an artistry of shading that is apparently as accurate as it is beautiful in the expression of the physical relief of the land-forms of this region.

The evident success which has attended the presentation of this map has properly resulted in the preparation of additional maps of this character by the U. S. Geological Survey. The experiment has been carried forward in various portions of the United States, chiefly the Appalachian Mountains region, where the necessary pronounced relief is present. In sequence, following the issuance of the Monument Springs map, shaded editions

PORTION OF WILLIAMSPORT SHEET
Reduction about one-half.

of the topographic sheets listed below have been issued. Even a casual perusal of these new maps will indicate the refinement and care with which the shading has been added to the normal contoured topography and the fine degree of success which has been obtained in the engraving processes. In the eastern United States, where humid conditions are present, tones of gray olive green have been used in place of the browns which were used on the Monument Springs quadrangle, and the effect is quite as accurate and pleasing. The new shaded sheets are as follows:

1. Monument Springs (Texas) quadrangle.....1921
2. Altoona (Pennsylvania) quadrangle.....1922
3. Philipsburg (Pennsylvania) quadrangle.....1922
4. Clintonville (West Va.) quadrangle.....1923
5. Hanging Rock (West Va.) quadrangle.....1923
6. Howard (Pennsylvania) quadrangle.....1923
7. Lockhaven (Pennsylvania) quadrangle.....1923
8. Ronceverte (West Va.) quadrangle.....1923
9. Tyrone (Pennsylvania) quadrangle.....1923
10. White Sulphur Springs (West Va.) quadrangle.....1923
11. Williamsport (Pennsylvania) quadrangle.....1923
12. Milton (Pennsylvania) quadrangle.....1924
13. Cave-in-Rock (Kentucky-Illinois) quadrangle.....1925
14. Washington, D. C., and vicinity (Road Map).....1925

Of these several sheets it is difficult to say which most accurately depicts the topography of the region. All are good. In general, however, it appears that wherever the topography is cast in large features, such as on the Altoona, Lockhaven, Williamsport and similar sheets, the result is most successful. In an area of relatively slight relief such as that represented by the Cave-in-Rock, Kentucky, quadrangle, the result is quite as interesting, but in general it is not so strong in its contrast as in the Appalachian or Rocky Mountain region, where bold and continuous ranges are present. On the Washington and vicinity map an interesting presentation of the topography is obtained, but one which, because of the small scale and lack of contouring, is to be regarded as more sketchy than detailed.

Students of physiography will be interested to see additional sheets in this series as they appear. Other eastern areas of type physiographic relief which would lend themselves to successful presentation as shaded topographic maps might easily be found

PORTION OF CAVE-IN-ROCK SHEET (KENTUCKY)
Reduction about one-half.

in the glaciated portions of upper New England, the highlands of southern New York, the Adirondacks, and the Catskills. Interesting features of western relief might also be brought out in the Black Hills, the Rocky Mountains, the Cascades, and the Coast ranges. Additional regions very suitable for presentation as shaded topographic maps are existent in many of the National Parks of the west, and also in some of those proposed for the eastern United States, particularly the Shenandoah of Virginia, the Great Smoky of Tennessee and the Mammoth Cave parks of Kentucky. The distinct advantage in issuing such maps for these regions would be that tourists from all parts of the United States would find these maps a distinct advantage and benefit to them while engaged in holiday pursuits, or more detailed explorations in these several regions.

The United States Geological Survey has also published a number of new shaded relief maps of various parts of the United States which will be of very special interest to physiographers. These maps are presented without contouring of topography. They include a map of the United States on a scale of 1:3,168,000, one of Alaska 1:2,500,000, and State maps of Ohio 1:380,160, and Kentucky 1:500,000. A shaded relief edition of the Arizona State map has also been issued on a scale of 1:500,000. There are in preparation for publication shaded relief maps of Pennsylvania, New York, New England, West Virginia, Colorado and Wyoming.

Old Capitol,
Frankfort, Ky.

X

A BIBLIOGRAPHY

Of the Geology and Paleontology of the John Day Region, Oregon*

ABEL, OTHENIO.

1. Grundzuge der Palaeobiologie der Wirbeltiere; John Day Formation, p. 603, Stuttgart, 1912.

BETTANY, G. T.

2. On the Genus Merycochoerus (Fam. Oreodontidae); Quar. Jour. Geol. Soc., Vol. 32, pp. 259-273, 1876. Describes 2 new spp.: M. leidyi and M. temporalis.

BLAKE, WILLIAM P.

3. Locality of Secondary Fossils in Oregon; Am. Jour. Sci., 2d Ser., Vol. 44, p. 118, 1867.

CALKINS, FRANK C.

4. A Contribution to the Petrography of the John Day Basin: Bull. of the Dept. of Geol., Univ. Calif., No. 3, pp. 109-172, 1902.

COLLIER, ARTHUR J.

5. The Geology and Mineral Resources of the John Day Region; Oregon Bur. Mines & Geol., Min. Res. Oregon, Vol. 1, No. 3, 1914.
6. Geology of the Columbia River Basin, between the John Day River and the Umatilla River; Oregon State Engineer, Co-op. Work John Day Project, pp. 31-35, 1916.

CONDON, THOMAS

7. Rocks of the John Day Valley; Overland Monthly, May, 1871, p. 393.
8. The Two Islands and What Came of Them; Portland, Oregon, 1902.

COPE, EDWARD DRINKER.

9. On Some of the Characters of the Miocene Fauna of Oregon: Proc. Am. Philos. Soc., pp. 18, 63-78: Pal. Bull. No. 30, pp. 1-16, 1878.
10. American Aceratheria; Am. Nat., Vol. 13, pp. 333-334, 1879. Rhinorceidae: Aceratheria truquianum Cope. n. sp., John Day of Oregon. Described from incomplete mandible.
11. A new Anchitherium; Am. Nat., Vol. 13, pp. 462-463, 1879.
12. Description of Archaelurus debilis and Hoplophoneus platycopis; Am. Nat., Vol. 13, p. 798a, b, 1879. Felidae: Archaelurus debilis Cope, gen. et sp. nov. Described from skull only. Hoplophoneus platycopis Cope, sp. nov. Described from skull only. Compared to other sabre-tooth cats.

---

*Revised reprint of pamphlet published at Frankfort, Ky., 1923.

13. On the Genera of Felidae and Canidae; Proc. Acad. Nat. Sci. Phila., Vol. 31, pp. 168-194, 1879. Felidae; Dinictis; pp. 169, 170, 173, 174, 176, 177. Nimravus; pp. 168, 169, 170, 173. "The genera with large canines or Machaerodontine line were then (early Miocene or Oligocene) represented by Dinictis and the feline line by Pseudaelurus," p. 174. "The oldest found Dinictis, Nimravus, etc., are the least specialized and they disappeared before close of Miocene time," p. 173. Dinictis cyclops, sp. nov., described, pp. 176-177, from the Truckee beds of John Day River, Oregon, Canidae: Temnocyon coryphaeus, sp. nov., p. 180, described. "This is the most abundant dog of the Truckee beds of the John Day country," p. 180. Icticyon crassivultus, sp. nov., pp. 190-192, described. Truckee Beds of the White River Tertiary, John Day River region, Oregon. Enhydrocyon, Cope, Bull. U. S. G. S. Terrs, V. 56, 1879. "Two species from White River beds of Oregon are known," p. 185. Summary of principal characters, Canidae and Felidae, pp. 193-194.

14. Second Contribution to a Knowledge of the Miocene Fauna of Oregon; Proc. Am. Philos. Soc., pp. 18, 370-376, Jan., 1880. Pal. Bull. No. 31, pp. 1-7, Dec., 1879.

15. Observations on the Faunae of the Miocene Tertiaries of Oregon; Bull. U. S. Geol. Surv. Terr., pp. 5, 56-69, 1879.

16. On the extinct species of Rhinoceridae of North America and their Allies, Bull. U. S. Geol. Surv. Terr., pp. 5, 227-237; Am. Nat., pp. 13, 771a-771j.

17. A new Hippidium; Am. Nat., Vol. 14, pp. 233, 1880. H. spectans.

18. Corrections of the geological maps of Oregon; Am. Nat., Vol. 14, pp. 457-458, 1880.

19. On Certain Tertiary Strata of the Great Basin; Proc. Am. Philos. Soc., Vol. 19, p. 61, 1880.

20. The Rodentia of the American Miocene; Am. Nat., Vol. 15, pp. 586-587, 1881.

21. The Tertiary Formations of the Central Region of the United States; Am. Nat., Vol. 16. pp. 177-195, 1882.

22. The Extinct Rodentia of North America; Am. Nat., Vol. 17, pp. 43-57, 165-174, 370-381, 1883. Pts. I-III.

23. The Vertebrata of the Tertiary Formations of the West; U. S. Geol. Surv. Terr., Vol. 3, pp. 762-1002, 1883.

24. The History of the Oreodontidae; Am. Nat., Vol. 18, pp. 280-282, 1884. A synoptic review of the Oreodonts and the Agriocheors, including evolutional comparison and tabular presentation of geologic range. Total number of species given as 35. The range is given as from the White River, John Day, North Fork (John Day?) Ticholetupus beds. and Loup Fork.

25. Synopsis of the Species of Oreodontidae; Proc. Am. Philos. Soc., Vol. 21, pp. 503-572, 1884.
26. The Vertebrate Fauna of the Ticholeptus Beds; Am. Nat. Vol. 20, pp. 367-369, 1886.
27. The Phylogeny of the Camelidae; Am. Nat., Vol. 20, pp. 611-624, 1886.
28. On two new Species of three-toed Horse from the Upper Miocene, with note on the Fauna of the Ticholeptus Beds; Proc. Am. Philos. Soc., Vol. 23, pp. 357-361, 1886.
29. The Perissodactyla: Am. Nat., Vol. 21, pp. 985-1007, 1060-1076, 1887.
30. A List of the Mammalia from the Miocene of Oregon; Am. Nat., Vol. ——, pp. 833, 1888.
31. On the Dicotylinae of the John Day Miocene; Proc. Am. Philos. Soc., Vol. 25, pp. 62-79, 1888.
32. The Artiodactyla; Am. Nat., Vol. 22, pp. 1079-1095; Vol. 23, pp. 113-136; 1888-89.
33. A Review of North American Species of Hippotherium; Proc. Am. Philos. Soc., Vol. 26, pp. 26, 429-458, 1889.
34. On a Species of Plioplarchus from Oregon: Am. Nat., Vol. 23, pp. 625-626, 1889. P. septemspinosus.
35. Scott: on The Mammalia of the Deep River Beds; Am. Nat., Vol. 28, pp. 790-791, 1894. A complimentary review of Scott's memoir of same title. Cope concludes that "The John Day Anchitheria equiceps, brachylophum and longicriste must be referred to Miohippus, while A. praestans is an Anchitherium."

DALL, WILLIAM HEALEY.

36. A Table of the North American Tertiary Horizons, correlated with one another and with those of western Europe, with annotations; U. S. Geol. Surv., 18th Ann. Rept., Pt. II, pp. 334, 340, 1898.

EATON, GEORGE F.

37. John Day Felidae in the Marsh collection: Am. Jour. Sc., Vol. 4, pp. 425-452. Dec., 1922.

EYERMAN, JOHN.

38. Preliminary Notice of a new Species of Temnocyon, and a new Genus from the John Day Miocene of Oregon; Am. Geol., Vol. 14, pp. 320-321, 1894. T. ferox. Hypotemnodon.
39. The Genus Temnocyon and a new Species thereof, and the new Genus Hypotemnodon, from the John Day Miocene of Oregon; Am. Geol., Vol. 17, pp. 267-287, 1896. T. ferox.

GIDLEY, JAMES WILLIAMS.

40. A new Genus of Horse from the Mascall Beds, with notes on a small Collection of Equine Teeth in the University of California; Bull. Am. Mus., Vol. 22, pp. 385-388, 1906. Archaeohippus.

HATCHER, JOHN BELL.

41. Origin of the Oligocene and Miocene Deposits of the Great Plains; Proc. Am. Philos. Soc., Vol. 41, pp. 113-131, 1902. Correlation table.

HAY, OLIVER PERRY.

42. Two new Species of Fossil Turtles from Oregon; Bull. of the Dept. of Geol., Univ. Calif., Vol. 3, pp. 237-241, 1903.

HYATT, ALPHEUS.

43. Trias and Jura in the Western States; Bull. Geol. Soc. Am., Vol. 5, pp. 395-434, 1894.

KING, CLARENCE.

44. U. S. Geological Exploration of the 40th Parallel; U. S. Geol. Surv., Vol. 1, Systematic Geology, pp. 413-423, 458, 1878.

KNOWLTON, FRANK HALL.

45. Fossil Flora of the John Day Basin, Oregon; U. S. Geol. Surv. Bull., p. 204, 1902.

46. Note in Correlating Ellensburg and Mascall Beds; U. S. Geol. Surv., Geol. Folio No. 86, p. 2, 1903.

LeCONTE, JOSEPH.

47. On the Great Lava Flood of the West, and on the Structure and Age of the Cascade Mountains: Am. Jour. Sci. (3), Vol 7, pp. 167-180, 259-267, 1874.

LEIDY, JOSEPH.

48. Remarks on a Collection of Fossils from Dalles City, Oregon; Proc. Acad. Nat. Sci. Phila., Vol. 22, pp. 111-113, 1870.

49. Remarks on Fossils from Oregon; Proc. Acad. Nat. Sci. Phila., Vol. 23, pp. 247-248, 1871.

50. Contributions to the extinct vertebrate Fauna of the Western Territories; U. S. Geol. Surv. Terr., Vol. 1, pp. 210-226, 1873.

LESQUEREAUX, LEO.

51. Fossil Plants of the auriferous gravel Deposits of the Sierra Nevada; Mem. Mus. Comp. Zool., Vol. 6, 1878.

52. Cretaceous and Tertiary Floras; U. S. Geol. Surv. Terr., Vol. 8, pp. 239-255, 1883.

53. Recent Determinations of Fossil Plants from Kentucky, Louisiana, Oregon, California, Alaska, etc., with Descriptions of new Species; Proc. U. S. Nat. Mus., Vol. 11, pp. 11-38, 1889.

MARSH, OTHNEIL CHARLES.

54. Notice of New Tertiary Mammals; Amer. Jour. Sci. (3), Vol. 5, pp. 407-410, 485-488, 1873. (See Scientific Papers, Marsh, Vol. I, Peabody Museum Library, Yale.) Includes John Day spp.: Oreodontidae: Oredon occidentalis sp. nov. Rhinoceridae: Rhinoceros annectens, sp. nov.

55. Notice of New Equine Mammals from the Tertiary Formation; Am. Jour. Sci. (3), Vol. 7, pp. 247-258, 1874. (See Scientific Papers, Marsh, Vol. 1, Peabody Museum Library,

Yale.) Includes John Day spp: Equidae: Miohippus annectens, gen. et sp. nov. Anchitherium anceps, sp. nov.

56. Ancient Lake Basins of the Rocky Mt. Region; Am. Jour. Sci. (3), Vol. 9, pp. 49-52, 1875. References are made to the John Day Basin of Oregon and Rev. Thos. Condon, Oregon State Geologist.

57. Notice of New Tertiary Mammals; Am. Jour. Sci. (3), Vol. 9, pp. 239-250, 1875. (See Scientific Papers, Marsh, Vol. I. Peabody Museum Library, Yale.) Includes John Day spp.: Suidae: Thinohyus lentus, gen. et sp. nov. Thinohyus socialis, sp. nov. Oreodontidae: Eporeodon, gen. nov.

58. Notice of Some New Vertebrate Fossils; Am. Jour. Sci. (3), Vol. 14, pp. 249-256, 1877. (See Scientific Papers, Marsh, Vol. I, Peabody Museum Library, Yale.) Includes John Day sp.: Chalicotheriidae: Moropus distans, gen. et sp. nov.

59. The gigantic Mammals of the Order Dinocerate; U. S. Geol. Surv., 5th Ann. Rept., pp. 243-302, 1885. Eporeodon socialis, figs. 128, 129.

60. Description of Tertiary Artiodactyles: Am. Jour. Sci. (3), Vol. 48, pp. 259-274, 1894. (See Scientific Papers, Marsh, Vol. 3, Peabody Museum Library, Yale.) Includes John Day sp.: Suidae: Reference on page 271 to Thinohyus, described Am. Jour. Sci. (3), Vol. 9, pp. 239-250.

61. The Reptila of the Baptanodon Beds: Am. Jour. Sci. (3), Vol. 50, pp. 405-406. Rhinoceridae: Reference is made to discovery of Trigonia from the Blue Mts. of Eastern Oregon. Indefinite.

MATTHEW, WILLIAM DILLER.

62. A Provisional Classification of the fresh-water Tertiary of the West: Bull. Am. Mus., Vol. 12, pp. 19-75, 1899.

63. A Lower Miocene Fauna from South Dakota: Bull. Am. Mus., Vol. 23, pp. 169-219, 1907.

MERRIAM, JOHN CAMPBELL.

64. Report on the Expedition to the John Day fossil fields; Sci. Asso. Univ. Calif. Proc. Gen. Meetings, Vol. 1, pp. 3-10, 1899.

65. Classification of the John Day Beds (abstr.): Science, n. s., Vol. 11, pp. 219-220, 1900.

66. Geological Section through the John Day Basin (abstr.), Bull. Geol. Soc. Am., Vol. 12, pp. 496-497: Jour. Geol., Vol. 9, pp. 71-72, 1901.

67. The John Day Fossil Beds: Harper's Monthly Mag., Vol. 102, pp. 581-590, 1901.

68. A Contribution to the Geology of the John Day Basin: U. of Cal., Vol. 5, pp. 269—, 1901. Geology, faunae and florae of the Cretaceous (Chico and Knoxville), Eocene (Clarno), Oligocene (John Day series), Columbia lava, Miocene (Mascall), Pliocene (Rattlesnake), Quarternary.

69. Carnivora from the Tertiary Formations of the John Day Region; U. of Cal., Vol. 5, No. 1, pp. 1-64, 1906.
Brief notes on the Tertiary formations of the John Day region. Description of the Canidae and Felidae. John Day carnivores more advanced in structure than White River carnivores, less advanced than Loup Fork carnivores.

70. Notes on the Canid Genus Tephrocyon; U. of Cal., Vol. 7, No. 18, p. 362, 1913. Reference is made to "The species Tephrocyon near to T. altigenis Cope from the John Day Series."

71. Relationships of Pliocene mammalian faunas from the Pacific coast and Great Basin provinces of North America; Bull. Univ. Calif., Dept. Geol., Vol. 10, pp. 421-443, 1917.

MERRIAM, JOHN C., and SINCLAIR, WILLIAM JOHN.

72. The Correlation of the John Day and the Mascall; Jour. Geol., Vol. 11, pp. 95-96, 1903. (abstr.)

73. Tertiary Faunas of the John Day Region; U. of Cal., Vol. 5, No. 11, pp. 171-205, Bull. Dept. Geol., 1907.
Important! This paper contains a good working bibliography of John Day up to 1907. The total known vertebrate fauna of the John Day to 1907.

NEWBERRY, JOHN STRONG.

74. Brief Description of Fossil Plants, chiefly Tertiary, from western North America; Proc. U. S. Nat. Museum, Vol. 5, pp. 502-514, 1883.

75. The later extinct Floras of North America; U. S. Geol. Surv. Mon. 35, 1898. (Posthumous editor, Arthur Hollick). Tables of distribution. p. 140. et seq.

OSBORN, HENRY FAIRFIELD.

76. Correlation between Tertiary Mammal Horizons of Europe and America, with Third Trial Sheet; Ann. N. Y. Acad. Sci., Vol. 13, pp. 1-72. 1900. Correlation of John Day with European horizons.

77. Tertiary Mammal Horizons of North America; Bull. Am. Mus., Vol. 23, pp. 237-253, 1907.

78. Cenozoic Mammal Horizons of Western N. A.; Bull. U. S. Geol. Surv., No. 361, pp. (John Day) 22, 23, 64-69, (Mascall) 22, 64, 68, 114-115, (Rattlesnake) 22, 64, 81, 115-118, 1909.

79. The Age of Mammals, pp. (John Day) 42, 204, 224, 226-233, 358, 359, (Mascall) 41, 282-283, 288-291, 358, 359, (Rattlesnake) 41, 309, 341, 357, 358, 359, 1910.

80. Ten Years' Progress in vertebrate Paleontology; Correlation and paleogeography: Bull. Geol. Soc. Am., Vol. 23, pp. 232-256, 1912.

RUSSELL, ISRAEL COOK.

81. Notes on the Geology of southwestern Idaho and southeastern Oregon: U. S. Geol. Surv. Bull., 217, 1903.

82. Preliminary Report on the Geology and Water Resources of Central Oregon: U. S. Geol. Surv. Bull. 252, pp. 58-60, 1905.

SCOTT, WILLIAM BERRYMAN.

83. Beitraege zur Kentniss der Oreodontidae; Morph. Jahrb., Vol. 16, pp. 319-395, 1890.

84. On a New Musteline from the John Day Miocene; Am. Nat., Vol. 27, p. 658, 1893. Parictis princeous, gen. et sp. nov. Description of fragmentary "mandibular ramus containing only p^2 and p^3 but displaying the alveoli of the other teeth, which was found in the John Day beds at Silver Wells, Oregon." "The John Day beds have hitherto yielded no members of the family. For this reason, even scanty fragments are of importance."

85. The Mammals of the Deep River Beds; Am. Nat., Vol. 27, pp. 659-662, 1893. "Deep River Beds" formation; Upper D. R. B. = "Ticholeptus Beds" Cope. Lower D. R. B. = "John Day." A preliminary correlation made as a result of the studies and vertebrate collections in the Deep River Valley by the Princeton Expedition in 1891.

86. On the Tertiary lacustrine Formations of North America; Brit. Assoc. Adv. Sci. Rept., pp. 681-682, 1895.

87. The selenodont Artiodaetyla of the Uinta Eocene; Trans. Wagner Free Inst. Sci., Phila., Vol. 6, 1899.

88. History of Land Mammals in the Western Hemisphere, pp. (John Day) 17, 30, 116, 375, 543; (Rattlesnake) 127, 1913.

SINCLAIR, WILLIAM JOHN.

89. The Discovery of a new fossil Tapir in Oregon; Jour. Geol., Vol. 9, pp. 702-707, 1901. Protapirus robustus.

90. Mylagaulodon. a new Rodent from the Upper John Day of Oregon; Am. Jour. Sci. (4), Vol. 15, pp. 143-144, 1903.

91. New or Imperfeetly Known Rodents and Ungulates from the John Day Series; U. of Cal., Vol. 4, No. 6, pp. 125-143, pls. 14-18, July, 1905. Rodents: Peromyseus parvus, sp. nov. Entoptychus sperryi, sp. nov. Entoptychus rostratus, sp. nov. Ungulates: Hypertragulus, sp. Allomeryx planiceps, gen. et sp. nov. Elotherium ealkinski, sp. nov. Thinohyus (Bothrolabis) deeedens Cope. Thinohyus (Bothrolabis) osmonti, sp. nov. Mesohippus Aeutidens, sp. nov. Summary deseriptions and comparisons. Photographie and line figs. of skeletal parts.

92. Some Edentate-like Remains from the Mascall Beds of Oregon; U. of Cal., Vol. 5, No. 2, pp. 65-66, 1906, Author notes that (Moropus distans, Marsh, senes) described as an Edentate is more probably a Chalieothere.

SMITH, GEORGE OTIS, and WILLIS, BAILEY.

93. Contributions to the Geology of Washington: U. S. Geol.

Surv., Prof. Paper No. 19, pp. 16-18, 1903. Correlation of Manatash Formation with the Upper Clarno.

STEARNS, ROBERT E. C.

94. Fossil land Shells of the John Day Region, with notes on related living Species; Proc. Wash. Acad. Sci., Vol. 2, pp. 651-660, 1900.

95. Fossil Shells of the John Day Region; Science, n. s., Vol. 15, pp. 153-154, 393, 1902.

96. Fossil Mollusca from the John Day and Mascall Beds of Oregon; Bull. of the Dept. of Geol., Univ. Calif., Vol. 5, No. 3, pp. 67-70, 1906.

STERNBERG, CHARLES H.

97. The Miocene Beds of the John Day River, Oregon; Kansas City Rev., Vol. 4, pp. 540-542, 1881.

98. John Day Promerycochoeri, with Descriptions of Five New Species and One New Subgenus; Am. Jour. Sc., Vol. 1, pp. 215-244. March, 1921.

99. John Day Eporeodons with Descriptions of New Coenera and Species; Am. Jour. Sc., Vol. 2.

100. Two New forms of Agriochoerus. Am. Jour. Sc., Vol. 2, pp. 111-119. Aug., 1921.

THORPE, MALCOLM RUTHERFORD.

101. The Geological History of the Oreodonts. Jour. Manu., Vol. 6, No. 2, pp. 69-82. May, 1925.

WASHBURNE, CHESTER.

102. Notes on the Marine Sediments of Eastern Oregon; Jour. Geol., Vol. 11, pp. 224-229, 1903. This paper establishes the limestones of Baker County, as carboniferous; Wallowa Lake region, Triassic; Silver Lake region, Jurassic; Wheeler county, Cretaceous (Knoxville); Crooked River, Spanish Gulch, Cretaceous (Chico).

WHITE, CHARLES ABIATHAR.

103. On marine Eocene fresh-water Miocene and other fossil Mollusca from western North America; U. S. Geol. Surv., Bull. 18, 1885.

WHITNEY, JOSIAH DWIGHT.

104. Notice of the occurrence of the Silurian Series in Nevada; Proc. Cal. Acad. Sci., Vol. 3, p. 309, 1867.

WILLIAMS, IRA A.

105. Geology of the Clarno dam site; Oregon State Engineer, Coop. Work John Day Project, pp. 82-88, 1916.

WILLIS, BAILEY.

106. John Day Basin, Oregon, and Columbia Plateau; Prof. paper U. S. Geol. Surv., No. 71, pp. 826-831, 1912.

WORTMAN, JACOB LAWSON.

107. The extinct Camelidae of North America and some associated

forms; Bull. Am. Mus., Vol. 10, pp. 93-142, 1898.
Presented complete to 1917 and with five recent title additions, Oct. 11, 1927. Aug., 1921.

Yale University,
New Haven, Conn.

XI

GEOLOGY OF THE AMORY GAS FIELD*

The existence of commercial deposits of petroleum and natural gas under considerable areas within the State of Mississippi has been assumed by geologists generally for many years. Oil and gas operators, however, while admitting the possibility of important producing Paleozoic sands accompanied by favorable structure at reasonably shallow depths in this part of the great

CRETACEOUS UPLAND NEAR AMORY

The view is near the Amory Petroleum Co. No. 2, well about eight miles east of Amory, Monroe County, Mississippi.

valley, have until recently looked askance at the territory. Their doubts have been engendered presumably by a rather considerable amount of costly and unproductive drilling exploration. A record of intermittent prospecting failures therefore reserved for the year 1926 a distinct novelty in Mississippi.

The unexpected event was the bringing in on October 5 of a large gasser, the Carter No. 1, at a depth of 2,470 feet, about six miles east of Amory in Monroe County. This well produced when flush 4,552,860 cubic feet[1] open flow daily. The honor of producing Mississippi's first commercially important natural gas well belongs to the Amory Petroleum Company, the geological field work being executed by H. D. Easton of Louisiana. Upwards of a year later—November 13, 1927, to be exact—a

*Oil and Gas Journal, pp. 58, 126, 128; January 26, 1928.

[1]Gasser Strengthens Cincinnati Arch Oil Probability. H. D. Easton, The Oil Weekly, Vol. 44, No. 6, pp. 29-30, January 28, 1927.

second and very important gas well—the Rye No. 1—was brought in by the Natural Gas and Fuel Oil Company. The location of the new well, reported to be producing about three to four million cubic feet of natural gas daily, is about fifteen miles southeast of Amory. The scope of the new Mississippi gas field is therefore considerably extended. In the Rye well a flow of about 50,000 cubic feet was encountered at 2,234 feet while the large production came at seven feet in the producing sand at 2,693 feet. It was finally deepened to 2,702½ feet and showed in the record 15 feet of broken sand when completed.

A reconnaissance of the gas-producing area near Amory, executed by the writer, personally, on March 17, 1927, indicates that the selection of the original and subsequent drilling locations took into consideration a number of important geological factors. The nature of the surface sediments in the producing region—all unconsolidated Tuscaloosa (Cretaceous) sands, gravels and clays—must surely have caused many perplexities. Other not inconsiderable technical embarrassments will undoubtedly arise as the development proceeds. With two large gassers producing, and upwards of ten reasonably deep drillings in progress, a bona fide campaign of regional explorations is now well under way.

The broad geological features involving oil and gas production in the vicinity of Amory are simple and well understood. The detail, possibly complex, will certainly never be known definitely. Geographically the field producing east and southeast of Amory is located close to, if not exactly upon, the crest of the Cincinnati arch. In this part of northeastern Mississippi, this great fold is rapidly plunging along an axial line to the south 45 degrees west. The surface rocks are chiefly Tuscaloosa in age, sands, gravels and clays. Here and there, however, there are outliers, somewhat reddish sands evidently of Eutaw age. These unconsolidated sediments give little, if any, dependable criteria at the surface as to what detailed subsurface structural conditions may be. The result of several drillings including the Carter and Rye wells indicates so far as unconsolidated embayment deposits are concerned that the Cretaceous in this locality may range from about 600 to 700 feet in thickness. Some discernible variability in the unconsolidated portion indicates

the presence of an angular erosional unconformity as has long been suspected between the lowermost Mesozoic and uppermost Paleozoic sediments. This unconformity is probably also a disconformity.

The drill cuttings from a part of Carter No. 1 well have been studied by Hugh D. Miser of the U. S. Geological Survey, and

MISSISSIPPI'S FIRST GAS WELL

This is the Carter No. 1 drilled by the Amory Petroleum Co. into large gas production October 5, 1926.

his descriptions, from 985 feet to 2,465 feet, covering the most questionable and the producing portion of this very important record, are given herewith. The stratigraphic divisions indicated for the record have been made by the writer. An important observation in this connection is that the penetrated divisions of the Chester are somewhat thicker and more argillaceous here than on outcrop in the type localities in Kentucky.

Record Of The Carter No. 1 Gas Well

Monroe County, Mississippi

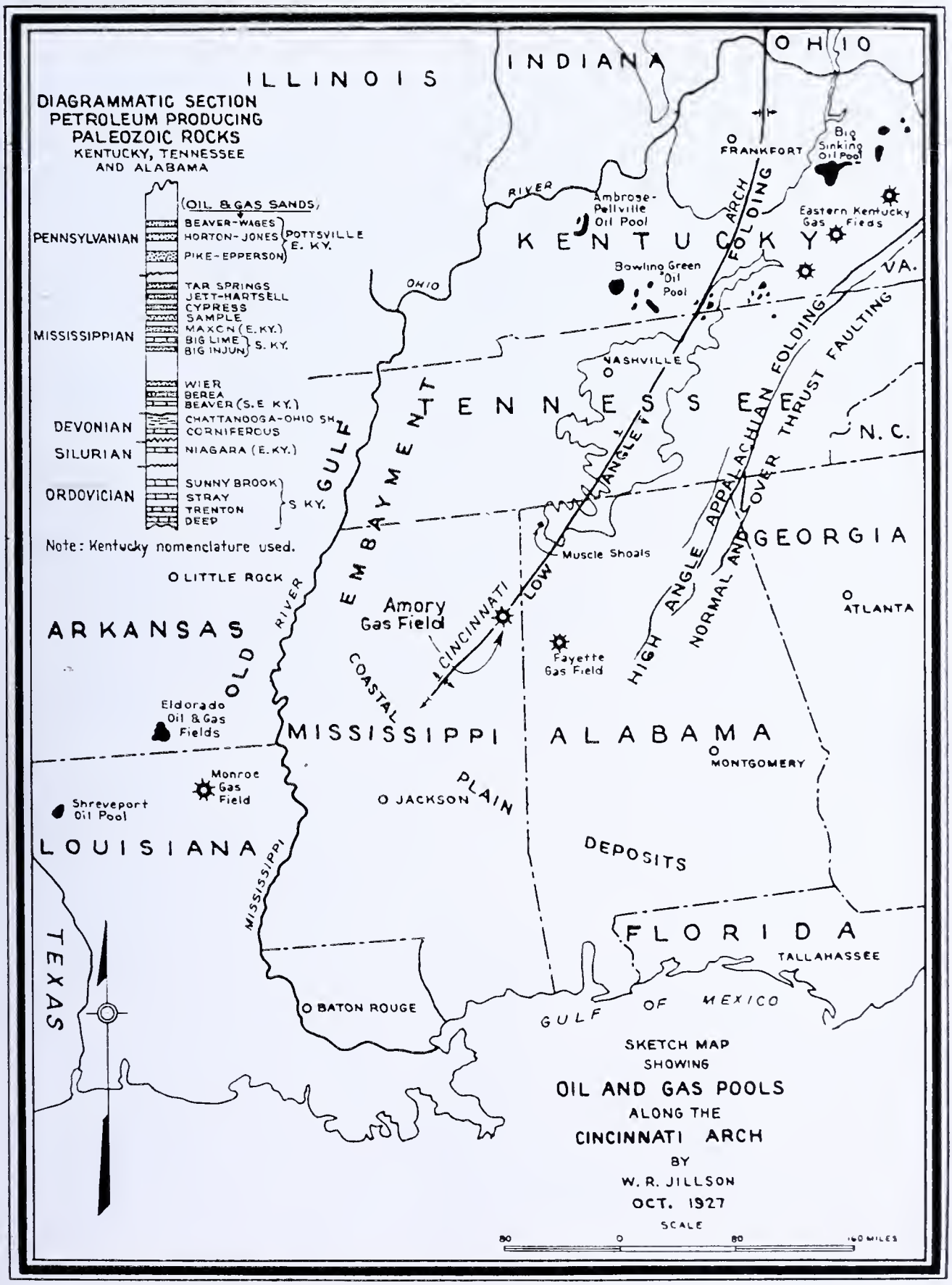
Paleozoic (Pennsylvanian-Mississippian undifferentiated)

985	Gray, sandy, earthy material	Pottsville
1030	Sand, light brown, coarse	
1045	Sand, light brown, fine	
1050	Sand, gray	
1145	Shale, gray, soft	
1190	Sand and lime mixed	
1200	Sand, fine white	
1225	Sand, white and black shale	
1230	Sand, white	
1240	Sand, white	
1250	Sandy, rusty, cemented material	
1335	Sand, brown	
1365	Sand, white	
1415	Sand, brown	
1440	Sand, white	
1462	Shale, bluish black, clay	
1468	Sand, fine white	

MISSISSIPPIAN

1495	Sandstone, dark calcareous	Leitchfield Formation (Buffalo Wallow F.)
1520	Clay, light bluish shaly	
1530	Clay, light bluish shaly	
1570	Sandy, earthy calcareous material	
1590	Shale, bluish-black	
1595	Shale, bluish-black	
1675	Shale, bluish-black	
1755	Shale, dark sandy	
1865	Sand, white	Tar Springs
1900	Sand, white	
1917	Sandstone, white	
1925	Sandstone, gray	
1970	Shale, black	This looks like late Mississippian or Pennsylvanian.
2100	Shale, dark gray, sandy; contains fossils.	
2100	Shale, grayish black fissile	
2160	Shale, grayish black fissile	
2200	Limestone, dark gray (fossils), and grayish black fissile shale	Glen Dean
2240	Shale, mottled green and brown	
2300	Shale, green	
2315	Shale, green	
2340	Shale, green	

2375 Limestone, dark gray, fossiliferous, and dark shale.
2400 Shale, dark fissile.
2460 Shale, dark fissile, and one piece of gray sandstone.
2465 Shale, dark gray fissile, and pieces of gray sandstone; the shale contains fossils.
2470 Sandstone, gray (Hardinsburg); "Jett oil and gas sand."
Total depth (reported), 2,470 feet.



AMORY GAS FIELD AND ADJACENT OIL AND GAS POOLS ALONG THE CINCINNATI ARCH

Originally it was thought because of its depth that this well must be producing from some deep Paleozoic formations, and many references were made to the Silurian as well as more ancient sediments, the Upper and Middle Ordovician. A study of the fossils and a careful comparison of the lithology revealed by drill cuttings indicates in the opinion of P. V. Rorendz and H. D. Miser that that part of the record between 2,200 feet and the bottom of the drilling was in Carboniferous rocks. The writer's own opinion based upon a study of this record and comparison of it with the known stratigraphic section exposed in northwestern Alabama is that the producing sand is in the upper part of the lower Carboniferous (Chester-Mississippian).

The most logical formation to produce oil and gas in this group is the Hartsell sand so petroliferous on outcrop in northwestern Alabama. This formation is a true silica sand underlying the Golconda limestones. It has been correlated by Charles Butts with the Hardinsburg[2] sandstone of Kentucky. It has further been shown that the Hardinsburg sandstone in Kentucky is the same as the chief producing sand of northern Ohio County —the "Jett."[3] From the "Jett" sand in Ohio County alone, there was produced in Kentucky during the past year—October, 1926, through September, 1927—a total of 974,218 barrels of oil. At the present time this sand is producing about 6,500 barrels of petroleum a day and rapidly increasing. On outcrop this sand is not petroliferous in Kentucky. At many points somewhat below the outcrop, it produces both oil and gas in Western Kentucky. Its recognition in northwestern Alabama as a formerly highly petroliferous formation, coupled with its productivity in the Armory field, establishes it as one of the really important oil and gas horizons in the upper divisions of the Paleozoic group in the midlands between the western face of the Cumberland plateau and the main waters of the Mississippi River.

At the present time there are several drillings prospecting the Amory gas sand (Hartsell sandstone-chester). The Drill No. 1 of the Amory Petroleum Company is down 2,350 feet, the Hall No. 1 of the same company is down 2,397 feet, and the Durrit

---

[2]Geology of Alabama, Alabama Geological Survey, Special Report No. 14, p. 195, 1926.

[3]New Oil Pools of Kentucky. Jillson, W. R., Kentucky Geological Survey, Series XI, Vol. 12, p. 10, 1926.

No. 1 of the Quincy Oil and Gas Company was dry at 3,075 feet. Other drillings, including the Ocker No. 1, Crook No. 1, Day No. 1, Searvey No. 1, and Taylor No. 1, are going forward in this important field and vicinity at lesser depths. The quality of the gas produced from the Carter No. 1 does not indicate, apparently,

TYPICAL MISSISSIPPI RIG

The wells all start rotary and at about 600 or 700 change to churn drilling. Physical relief is slight as shown here generally not more than 150 feet.

deposits of petroleum in close proximity to the producing well. This may be due to a high regional metamorphism which has always been strongly suspected as responsible for the Fayette Gas Fields and other light shows in northwestern Alabama.

The most important conclusion revealed by the bringing in of the successful Carter No. 1 and the Rye No. 1 wells, aside from the fact that natural gas exists here in large commercial quantities, is that the Hartsell sandstone (Chester) is now to be regarded definitely as an important producing horizon in northeastern Mississippi. At points somewhat removed to the northwest from the axis of the Cincinnati arch, immense quantities of petroleum may also eventually be found in this important siliceous bed. In the course of further exploratory drilling, which is now sure to follow throughout all of northern Mississippi and adjacent parts of Alabama, the Chester (Mississippian) sequence will certainly be adequately tested. As a result of this prospecting, other classic units, such as Tar Springs, Cypress and Sample sandstones, may finally be revealed to be quite as

important oil-and-gas producers here on the eastern shoulder of the old gulf embayment as much farther to the north in Western Kentucky.

Old Capitol,
Frankfort, Ky.

INDEX

A

Page

Allen County 13
American Journal of Science 57, 69
Amory Gas Field 143, 147
Appalachian District 16
Arkansas 101, 104
Ashley Pool 12
Asphaltic Coal 7
Austin, Moses 99

B

Barren County 13, 37
Bath County 105
Beaver Creek 25, 27
Beaver Dam Creek 37
Bed Rock Oil 28
Berea "Sand" 27, 28
Bibliography 111, 133
Big Injun "Sand" 27, 28
Big Lime 27
Big Sandy Valley 25
Big Sandy Valley, Map of 26
Big Sinking Pool 12, 15
Boone County 23
Bowling Green 17, 35
Boyd County 25, 102
Breathitt County 21
Brushy Mountain 75, 78, 80
Burt, Wm. A. 106
Butte Camp 63, 68

C

Cambrian 39
Carbon Cast Lava 57
Carver, Capt. Jonathan 92
Caucasians 90
Cave-in-Rock Sheet 130
Celina District 119
Cheatham County, Tenn. 83
Chester Limestone 17
Chickasaw Bluffs 90
Cincinnati Arch 35, 147
Cinnamon Peak 66
Cispus River 66
Civil War 25
Clay County 21
Clinton County 13, 121
Coal Operations 100
Columbia River 49
Columbian Forest Reserve 63
Connecticut 105
Consolidation Coal Co. 19
Corniferous "Sand" 28

INDEX—Continued

Page

Cougar Creek 54
Crab Orchard 80
Cretaceous 144
Cretaceous Sediments 31, 33
Cumberland County 121
Cumberland River 11, 31, 32
Cumberland River Valley 86

D

Deermont 74, 78
Devonian Limestone 86
Devonian 28
Dickson County, Tenn. 86
Dismal Creek 8
Dixie Highway 17
Dog Creek 86
Drake, E. L. 109

E

Edmonson County 7, 8, 10, 17, 37
Elgin Sandstone 69
Elkhorn Creek 19
Elliott, Lt. C. L. 53
Elliott County 27
Elm Creek 70
Emory River 76
Emory River Overthrust 73
Emory River Fault 78, 79
Estill County 12
Evolution 39

F

Fire Clay Coal 21
Florida, State of 90
Floyd County 21, 27
Footprints 70
France 89
Franklin 35
Fremont, Captain 50

G

Geographic Review 49, 63
Glasgow Junction 37
Grand Canyon 2
Grayson County 7, 8
Great Lakes 89
Green River 35, 38, 43
Green River Valley 3
Greenup County 102

H

Haddix-Coalburg Geosyncline 21, 22
Harpeth River Dome 81, 82, 84

INDEX—Continued

Page

Hart County 4, 17
Hartsell "Sand" 148
Hartsell Sandstone 149

I

Illinois, State of 103
Illinois State Historical Society 89
Iowa, State of 104
Iron Industry 104
Isle Royale 89

J

Jellico 21
Jessamine 35
Jesuit Priests 89
Jett Sand 147, 148
John Day Region 133
Johnson County 13, 25
Judd Well 86

K

Kalama River 53, 64
Kanawha County 23
Kansas, State of 69
Karst 17
Karst Country 35
Kentucky Academy of Science .....
..... 7, 10, 11, 16, 17, 18, 19, 20, 21, 23, 31, 33
Kentucky Crude Oil 11
Kentucky Geological Survey 5
Kentucky River 23
Kentucky State Historical Society 25
Kentucky, State of 104
Kerr, Bud 118
Kettle Creek 121
Knox County 21
Kyrock 7

L

Lafayette Formation 31
Fafayette National Park 3
Late Formations 64
Laurel Creek Dome 27
Law, John 97
Lawrence County 13, 25, 27
Lead, Industry of 94
Lee County 12, 13
Lee Sandstone 78
LeRoy Shales 69
Lexington Herald 39
Logan County 23
Lost Creek 54
Louisiana, State of 99

INDEX—Continued

Page

Louisville & Nashville Railroad 17
Lyon County 32

M

McCracken County 32
McCreary County 13, 108
Magoffin County 13, 21, 27
Mammoth Cave 1, 2, 37, 38
Marcom, Eugene 117
Marquette 91
Martin County 21, 25, 27
Maxton Sand 27, 29
Mayfield, S. M. 81
Mehl, Dr. M. G. 71
Mexican Plateau 125
Mexico 91
Michigan, State of 89, 103
Middle Creek 29
Mine Fork Dome 28
Mineral Explorations 89
Mingo County 23
Miser, Hugh D. 145
Mississippi, State of 143
Mississippian 28
Mississippi Valley 89
Missouri, State of 99
Monroe County, Mississippi 146
Monument Springs 125, 126
Moody, Dr. R. L. 71
Morgan County 78
Mt. Desert Island 3
Mt. Hood 63
Mt. Margaret 66
Mt. Ranier 2, 49
Mt. St. Helens 49, 55, 57, 58, 61, 63
Mt. St. Helens, Map of 67
Mt. Whittier 66
Munfordville 17, 35

N

Nashville, Chattanooga and St. Louis Railway 81
National Park 1, 2
Nemo 73
New England 131
New York, State of 25
Nolin River 7, 9, 10

O

Obed River 77, 78
Ohio River Valley 43
Ohio, State of 25
Oil and Gas Journal 87
Oklahoma 69, 101

INDEX—Continued

Page

Ordovician 28
Oregon, State of 133
Owen, Dr. David Dale 7

P

Paducah 32
Paint Creek Uplift 29
Paleontology 133
Pan American Geologist 1, 35, 73, 117, 125
Pawhuska 69
Pencil Cave 120
Pennsylvanian 27
Pennsylvania, State of 25
Perry County 21
Pigeon Creek 7, 8
Pine Mountain 19
Pleistocene 39, 43
Pottsville Sandstone 77
Pottsville Series 80
Powell County 12
Pyro Clastic Deposits 64

R

Renault, F. P. 98
Rock Oil 25
Rock Mountain Region 129
Ross Creek Pool 12
Rutherford Dome 35

S

Salem, Oregon 51
Salt Manufacture 103
Schoolcraft, H. R. 93
Silurian 28
Sinking Streams 35, 36
Sink Hole 17
Slate Hollow 19
Southern Appalachian Region 30
Spirit Lake 65, 68
Stalactites 4
Station Camp Pool 12
Stewart County 31, 33
St. Louis Limestone 17, 37
Stones River 120
Strawberry Mountain 66

T

Tampa 90
Tennessee Oil Pool 117
Tennessee River 31
Tennessee, State of 21, 31, 32
Tertiary 1

INDEX—Continued

Page

Topographic Maps 125
Topography Mammoth Cave 3
Toutle River 64, 65
Tradewater River 43
Trenton Section 120
Trigg County 32
Trout Lake 53
Tumwater Mountain 66

U

Upper Cretaceous 31

V

Valley-Filled Areas 43, 44
Verebrate Footprints 69
Virginia 3
Volcanic Activity 49

W

Wartburg Sandstone 78
Warren County 4, 13, 15, 17, 37
Washington 57
Wayne County 13
Waynesboro 31
Wentworth, C. K. 80
West Virginia 23
Whitehorse Mountain 78, 80
Whitley County 21
Wier "Sand" 28
Williamsport Sheet 128
Willow Grove 117, 118
Wilson Creek Dome 29
Wisconsin 104
Wolfe County 12

Y

Yale University 55, 61, 71, 141
Yellowstone 2
Yosemite 2

Form 45

557.3 J 565

Jillson

Sketches in geology

30 MAY 1951 5077 243477

Form 47 557.3 J 565

PENNSYLVANIA STATE LIBRARY

Harrisburg

243477

In case of failure to return the books the borrower agrees to pay the original price of the same, or to replace them with other copies. The last borrower is held responsible for any mutilation.

Return this book on or before the last date stamped below